

## MOTION AND TIME STUDY



By RALPH M. BARNES

MOTION AND TIME STUDY, *Third Edition*

WORK METHODS MANUAL

MOTION AND TIME STUDY APPLICATIONS



# MOTION AND TIME STUDY

BY

RALPH M. BARNES, M.E., PH.D.

*Professor of Industrial Engineering and Director of Personnel  
College of Engineering, University of Iowa*

THIRD EDITION

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## PREFACE

The great expansion of industrial activity in recent years has brought with it wider acceptance and greater use of motion and time study. Many practices in this field that once were accepted only in the most progressive plants have now become commonplace. Moreover, motion and time study has been applied in areas far removed from the factory, and all indications point to a greater extension of this work in the future. The main purpose of this revision of *Motion and Time Study* has been to enlarge upon certain phases of motion and time study and to include more and diverse illustrations and cases. In the revision the author has adhered to his original purpose of presenting the basic principles that underlie the successful application of motion and time study, supplementing each with illustrations and practical examples.

Most of the chapters have been thoroughly revised, and much new material has been added. There are five new chapters, dealing with the subjects of process analysis, gang process charts, activity charts, and man and machine charts. Action photographs have been included to aid the reader in learning the fundamental hand motions. Also included is new material on rating operator performance, the effect of practice, and motion and time study training programs.

The author has used the results of an industrial engineering survey of eighty factories which he recently made as a guide in evaluating and presenting the most successful techniques in general use. Likewise, information obtained from the Work Measurement Project conducted by the author has been helpful in revising the chapters on time study.

Summarized results of certain research studies conducted in the Industrial Engineering Laboratory at the University of Iowa have been incorporated in the text, with specific acknowledgments to those whose work is reported. To these and the many other people who have given valuable assistance the author wishes to express his great appreciation.

He is especially indebted to Harold Engstrom and his associates who, while at the General Electric Company, developed the methods and time values presented in Chapters 26 and 27.

RALPH M. BARNES

Iowa City, Iowa







## PREFACE TO FIRST EDITION

The present trend toward increased efficiency in all kinds of work has brought about a widespread interest in motion and time study. Wherever manual work is performed there is always the problem of finding the most economical way of doing the task, and then of determining the amount of work that should be done in a given period of time. This is ordinarily accompanied by some incentive plan of wage payment. Motion and time study provides a technique that is unequalled for finding methods of greatest economy and for measuring labor accomplishment.

The terms "time study" and "motion study" have been given many interpretations since their origin. Time study, originated by Taylor, was mainly used for rate setting; and motion study, developed by the Gilbreths, was largely employed for improving methods. One group saw time study only as a means of determining the size of the task that should constitute a day's work, using the stop watch as the timing device. Another group saw motion study only as an expensive and elaborate technique for determining a good method of doing work. Today the discussion of the comparative value of using either the one or the other of the two techniques has largely passed; industry has found that motion study and time study are inseparable, as their combined use in many factories and offices now demonstrates. Taking cognizance of present trends and recognizing the fact that motion study always precedes the setting of a time standard, we shall in this volume use the term "motion and time study" as referring to this broad field.

Since all manual work is done by means of the hands or other parts of the body, the study of body movements has been found to be a valuable approach to the problem of finding better ways of doing work. Training in the micromotion study technique is a valuable aid in analyzing and improving manual operations, i.e., in applying motion-economy principles. For this reason the technique of micromotion study has been presented in detail.

Micromotion study is defined as the study of the elements of an operation by means of a motion-picture camera and a timing device which accurately indicates time intervals on the motion-picture film.



This, in turn, makes possible the analysis of the elementary motions recorded on the film, and the assignment of time values to each. Micro-motion study may be used for two purposes: (1) to assist in finding the most efficient method of doing work; and (2) to assist in training individuals to understand the meaning of motion study and, when the training is carried out with sufficient thoroughness, to enable them to become proficient in applying motion-economy principles. The second purpose of micromotion study is by far the more important of the two.

The performance of manual work in an effective manner presupposes some understanding of the inherent capacities and abilities of the human body. Therefore, investigations bearing on manual work made by engineers, physiologists, and psychologists have been studied and such findings as seem most useful have been included in this volume. Although the material in Chapters 15, 16, and 17 has been discussed under the heading "principles of motion economy," it might, perhaps, have been more accurately designated as "some rules for motion economy and fatigue reduction." The writer has selected what material he could find that seemed to be useful in determining better methods of doing work. The twenty-two rules or principles presented in these chapters are not all of equal importance nor does this discussion include all of the factors which enter into the determination of better methods of doing work. However, it is hoped that this material may be of some value to those who have difficulty in finding a condensed treatment of the subject.

In presenting the technique of stop-watch study, the author has attempted to give those practices that result in most satisfactory time standards and to include simple examples to illustrate the methods.

The author has personally selected or developed the case material used for illustrations in this volume. Moreover, most of the material, in lithoprinted form, has had actual use in the classrooms of six colleges and universities and in many industries. The volume should, therefore, be of value to those supervising or engaged in manual work of any kind whatsoever. Workers as well as managers and engineers should profit from a study of this material. The many comments received from the users of the lithoprinted edition indicate that this material will serve not only as a textbook in technical colleges and universities but as a handbook in factories, stores, hospitals, homes, and on farms.

Over the period of several years during which this book has been in process of development, the author has had constant assistance and advice from industrial executives, engineers, and educators. To these



he would express his great indebtedness. His special thanks for assistance received are due to Professor David B. Porter of the College of Engineering, New York University, and to L. P. Persing, supervisor of wage rates at the Fort Wayne works of the General Electric Company.

RALPH M. BARNES

*Iowa City, Iowa*  
*March, 1937*







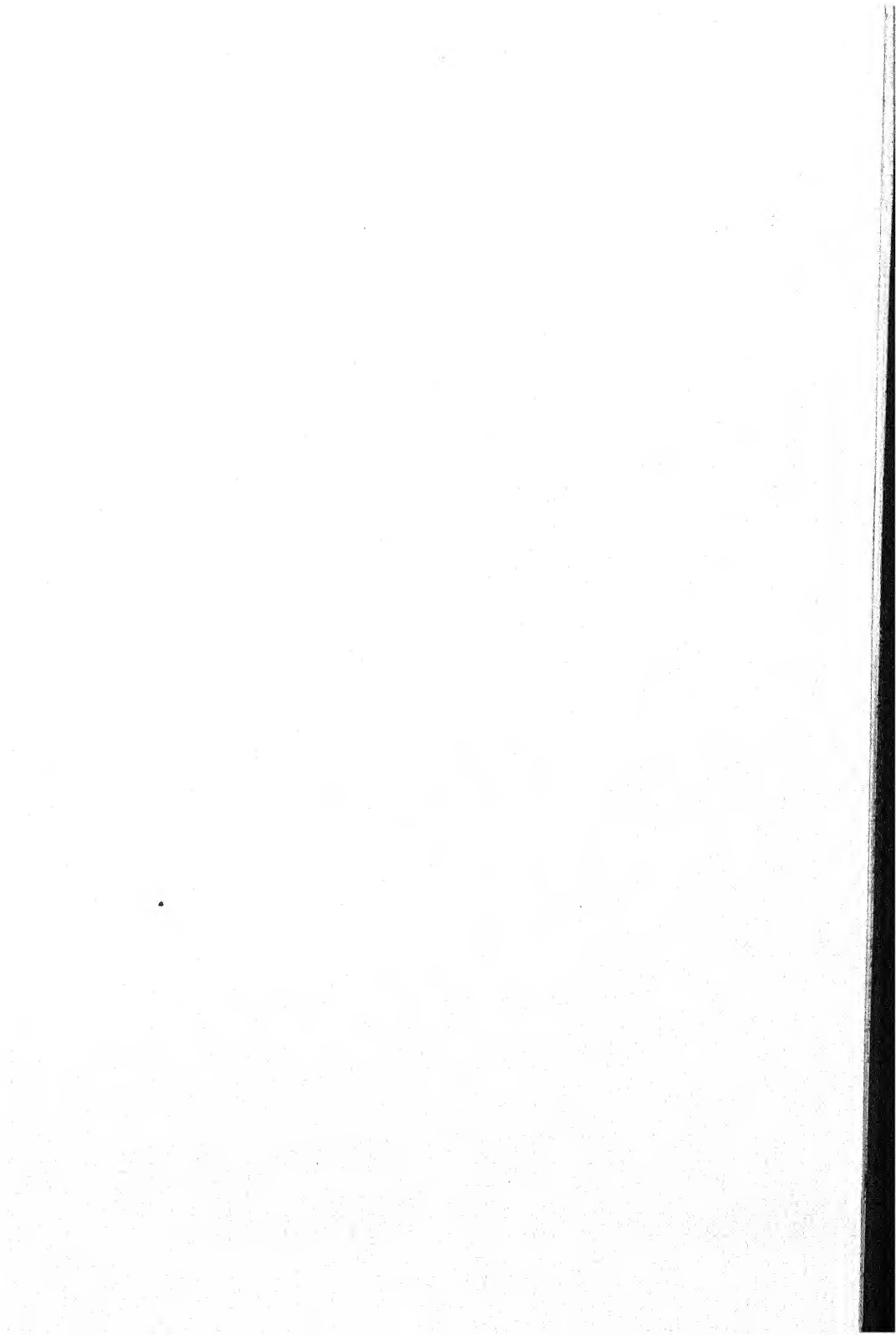
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## Process Analysis – Page 28

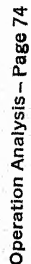


FIGURE 1. PICTORIAL



PRODUCTION										MACHINE EQUIPMENT AND TOOLING PRICE DETAIL									
OPER. NO.	PLANT	FEED PER MIN.	FEED PER MIN.	FEED PER MIN.	FEED PER MIN.	FEED PER MIN.	FEED PER MIN.	FEED PER MIN.	FEED PER MIN.	TOOL NAME OR NUMBER									
1										Revolving Stock Stop									
2	1 1/2"	215	548	.012	.15	2 1/4"	.35	.12		Multiple Cutter Turners with 2 Carbide Cutters									
3	3/4"	52	274	1/4"	—	3/4"	.15	.12		End Face & Form Tool with High Speed Steel Cutter									
4	1 1/2"	215	548	.007	.26	3/4"	.10	.12		Special Block & 2 Carbide Cutters									
5	3/4"	40	198	16 P	—	3/4"	.05	.12		Die Head with High Speed Steel Chasers to Cut 3/4"-6 Threads									
6	1 1/2"	75	198	.0045	1.10	3/4"	.85	.12		High Speed Steel Cutoff Cutter									

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### 3. Determining the Time Standard

STUDY NO. 8775										OBSERVATION SHEET									
ELEMENTS										LOWER LINE: READING									
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
1. Put case box with 3 batteries of sand, press sand down each line.										.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
2. Press sand down with the thumb stroke, strike off with the index stroke.										.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
3. Cut with index stroke of crop sand, turn over, lay, and replace box.										.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
4. Carry chain with core & feed, draw on each stroke.										.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
(1)										.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
(2)										.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
(3)										.09	.09	.09	.09	.09	.09	.09	.09	.09	.09
(4)										.09	.09	.09	.09	.09	.09	.09	.09	.09	.09

Page 372

MINUTES - 1-2-3-4-5										ELAPSED TIME IN MINUTES									
7:00										10 15 20 25 30									
7:30																			
8:00																			

Page 385

Case 2—Using Gang Mills (See 1B for 6-Lip Mill)										Time per Piece in Minutes									
Symbol										3-Jaw Chuck									
A (See Sketch Above)										On Thread Arbor in Div. Head									
B (See Sketch Above)										Square									
Feed 2 1/2"										Hex									
C										Square									
D										Hex									
E										Feed 2 1/2"									
F										Feed 3 1/2"									
G										Feed 2 1/2"									
H										Feed 3 1/2"									
I										Feed 2 1/2"									
J										Feed 3 1/2"									
K										Feed 2 1/2"									
1										1.05 0.95 1.35 1.2									
2										1.10 1.0 1.40 1.25									
3										1.15 1.05 1.5 1.25									

Page 401

CONDITION OF PLACE										SIZE OF OBJECT AND TYPE OF GRASP									
Amount of postholding required										Every Learned 2H									
CONDITION A										1									
Postholding to maintain this work, then releasing the object on the next stroke.										2									
CONDITION B										3									
Postholding of parts on or less definite location with open movement, simple three strokes of release, an immediate work and point of location.										4									
1										5									
2										6									
3										7									

Preceding Page 447

### 4. Training the Operator— Page 482

Instruction Sheet										OPERATION PROCEDURE FOR HANDLING AND INSPECTION OF BOTTLES 1-OUNCE FRENCH SQUARES									
Page 486										1. Pick up bottles (2 rows of 3)									
										Grasp 6 bottles (2 in left hand, 4 in right hand). Hold thumbs toward you and fingers away from you.									







## CHAPTER 1

### DEFINITION AND SCOPE OF MOTION AND TIME STUDY

The terms "time study" and "motion study" have been given many interpretations since their origin. Time study, originated by Taylor, was used mainly for determining time standards, and motion study, developed by the Gilbreths, was employed largely for improving methods. In recent years, the combined use of motion study and time study has become widespread. Common practice today requires that motion study and time study be used together since the two supplement each other. Taking cognizance of present trends and recognizing the fact that motion study usually precedes the setting of a time standard, we shall in this volume use the term "motion and time study" as referring to this broad field and as having the following meaning.

**Definition of Motion and Time Study.** Motion and time study is the analysis of the methods, of the materials, and of the tools and equipment used, or to be used, in the performance of a piece of work—an analysis carried on with the purpose of (1) finding the most economical way of doing this work; (2) standardizing the methods, materials, tools, and equipment; (3) accurately determining the time required by a qualified person working at a normal pace to do the task; and (4) assisting in training the worker in the new method.

Motion and time study is composed of four parts as the above definition shows. Although these parts may be considered separately, no one of them can be omitted entirely without seriously impairing the value of the study. Each of the four parts will be explained more fully.

**1. Finding the Most Economical Way of Performing the Operation.** The best way of doing a specific task is determined by a systematic study of the methods, materials, tools, and equipment used. Since all operations require some human effort or attention (even an automatic machine requires some attention), a minute analysis of the movements made by the worker in performing his task is a valuable approach to the problem of finding the best method. This analysis of the movements of the operator is called motion study. Motion study is commonly defined as the study of the motions used in the perform-



ance of an operation for the purpose of eliminating all unnecessary motions and building up a sequence of the most useful motions for maximum efficiency.

A study of the motions of the operator naturally requires that the outside factors affecting these motions be considered also. The two are intimately connected, for when the operator moves his hand he makes contact with something. He assembles a part, uses a screw-driver, starts a machine, etc. A study of the materials, tools, and equipment, as well as of the motions themselves, is necessary. One material may have inherent qualities which make it superior to others for some specific use; so also may a tool or a machine. To illustrate, brass may be substituted for steel because its better machinability may more than offset its greater cost per pound; a high-speed steel drill may be substituted for a carbon steel one, or a semi-automatic machine may be used instead of a hand-operated one; all because in the particular case one material, tool, or machine is more economical than the other. Furthermore, it is possible that conditions such as lighting, heating, ventilation, vibration, and noise which surround the job may affect the output. These conditions should be adjusted to insure the greatest comfort to the worker and to give the greatest overall economy.

"Best way," "optimum manner," and "method of maximum efficiency" are some of the terms denoting the object of this first phase of motion and time study. To prevent confusion, it is important that a clear meaning be assigned to these terms. In all cases the object is to find the best way, *all factors* considered. That means that the economy in dollars and cents be considered as well as the economy in motions, materials, tools, and equipment. For example, a magazine-fed, motor-driven pencil sharpener might be the *best* device for sharpening pencils, but for the small office the hand-operated one is *most economical*. Therefore, what may be the best way in one case may not be the best way in another case. It should also be added that the best method for one operator may not be the best method for another operator. The determination of the method of greatest economy for a specific job, giving consideration to all factors affecting the work and the operator, is the purpose of this first part of motion and time study.

**2. Standardizing the Operation—Written Standard Practice.** After the best method for doing the work has been determined, this method must be standardized. The particular set of motions, the size, shape, and quality of material, the particular tools, jigs, fixtures, gauges, and



the machine or piece of equipment must be definitely specified. All these factors, as well as the conditions surrounding the worker, must be maintained after they have been standardized. A written standard practice giving a detailed record of the operation and specifications for performing the work is the most common and satisfactory way of preserving the standards.

**3. Determining the Time Standard.** Motion and time study may be used to determine accurately the standard number of minutes or hours that a qualified worker should take to perform the operation when working at a normal pace. This time standard converted into money value, as it often is, is called a piece rate. Piece rates are usually expressed as so many dollars per hundred pieces. In other cases, the standard time value is the basis for any one of the many different incentive wage-payment plans. This third part of motion and time study is sometimes referred to as rate setting.

The most common method of measuring manual work is the stop-watch time study. The operation to be studied is divided into small elements, and each of these elements is accurately timed with a stop watch. A selected or representative time value is found for each of these elements, and the time values are added together to get the total selected time for performing the operation. The speed exhibited by the operator during the time study is rated or evaluated by the time-study observer, and the selected time is adjusted by this rating factor so that a qualified operator, working at a normal pace, can easily do the work in the specified time. This corrected time is called the normal time. To this normal time are added allowances for personal time, fatigue, and delay, the result being the standard time for the task.

This standard time should permit a qualified operator to work at a normal pace indefinitely without undue fatigue. In fact, the time standard is usually set at such a level that the average employee can readily do 20 to 30 per cent more work than the standard requires. Therefore, when a wage incentive is used it is within the range of possibility for every qualified employee to do more work than the standard calls for and thus earn extra wages. The straight piece-rate plan of wage incentive, for example, rewards the worker in direct proportion to his output. The employee is usually guaranteed his hourly base rate irrespective of his output.

**4. Training the Operator.** A carefully developed method of doing work is of little value unless it can be put into effect. It is necessary to train the operator to perform the work in the prescribed manner.



Where but one or a few persons are employed on a given operation and where the work is relatively simple it is customary to train the operator at his work place. The foreman, motion and time study analyst, a special instructor, or a skilled operator may act as the teacher. In most cases it is the foreman who is responsible for training the operator, and the foreman often depends upon the motion and time study department for assistance in this task. The written standard practice or the element breakdown sheet is a valuable aid to the foreman in job training. When large numbers of employees must be trained for a single operation the training is sometimes carried on in a separate training department. Charts, demonstration units, and motion pictures are frequently used to advantage in such a training program.

**Scope.** In order to gain perspective and to show relationships it seems desirable to list in tabular form the tools and techniques of motion and time study (see Fig. 1) and also to show the entire field (see Fig. 2). The procedure of making a motion and time study follows a fairly definite pattern, the several steps of which are shown in Fig. 2 in some detail. This chart also outlines the material to be presented in the remainder of the book.

Although motion and time study is most commonly applied in the factory and the office, the principles are universal and may be equally effective wherever manual work is performed. For example, banks, mail-order houses, department stores, and supermarkets have obtained worth-while results from the application of the principles to their activities. Great strides also have been made in simplifying work on farms, and county agents in many states are now giving instruction in motion and time study as a part of their regular programs. In recent years considerable attention has been given to the proper design and arrangement of the home kitchen and laundry.<sup>1</sup> During the war thousands of men in various branches of the armed forces were given training in motion and time study, and this technique was used successfully in increasing efficiency in many different areas. There are many indica-

<sup>1</sup> Mary K. Heiner and Helen E. McCullough, "Kitchen Cupboards That Simplify Storage," *Bulletin* 703, New York College of Home Economics at Cornell University, 1947; "A New Look at the Kitchen," *The Architectural Forum*, Vol. 84, pp. 155-158, February, 1946, and pp. 187-190, March, 1946; Myrna Johnston and L. M. Comstock, "Your Kitchen Should Have What You Need Where You Need It When You Need It," *Better Homes and Gardens*, Vol. 24, No. 2, pp. 15-23, October, 1945; W. Burger, "Wegleitung zur Gestaltung der Küche" (A Guide for the Layout of Kitchens), *Schweizerische Bauzeitung*, Vol. 65, No. 36, pp. 500-505, September 6, 1947.



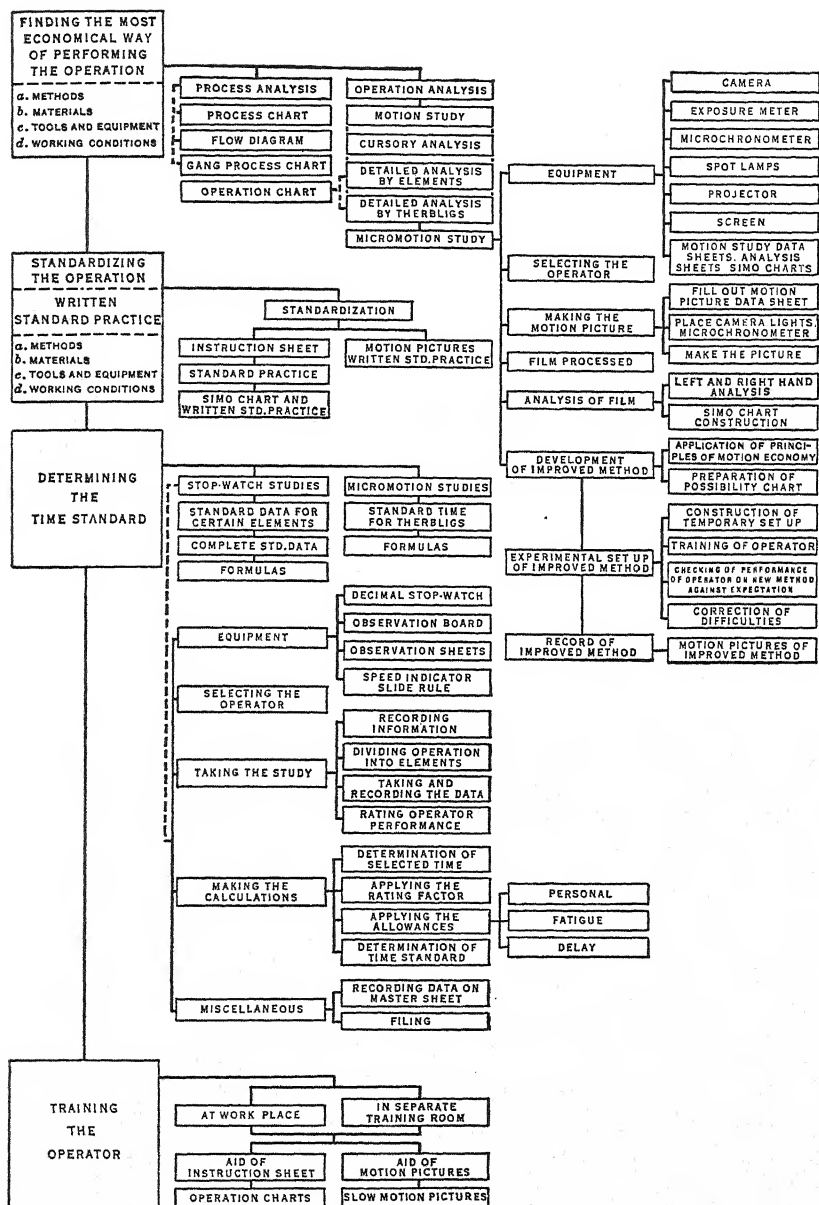


Fig. 2. Scope of motion and time study.



tions that the next few years will see widespread use of motion and time study in fields not now employing it.

**Motion and Time Study but a Part of Industrial Engineering.** Although the broad view of motion and time study has been presented, no attempt is being made to expand it to include the entire field of industrial engineering. In recent years there has been a tendency in this direction.

With competent engineers directing the use of motion and time study work, it frequently happens that a preliminary study of a single operation may quite properly lead to a complete investigation of an entire process, even involving the redesign of the product and an entirely new layout of manufacturing equipment. Such an investigation is beyond the scope of motion and time study and should more properly be classed under the broader field of industrial engineering.



## CHAPTER 2

### HISTORY OF MOTION AND TIME STUDY

In order to understand how time study has come to have the broad meaning presented in the preceding chapter, it is necessary to go back and investigate the origin and examine the use that has been made of time study and motion study during the last fifty years.

#### TAYLOR'S USE OF TIME STUDY

It is generally agreed that time study had its beginning in the machine shop<sup>1</sup> of the Midvale Steel Company in 1881, and that Frederick W. Taylor was its originator. Taylor's definition and explanation of time study is:<sup>2</sup>

Time study is the one element in scientific management beyond all others making possible the "transfer of skill from management to men." . . . "Time study" consists of two broad divisions, first, analytical work, and second, constructive work.

The analytical work of time study is as follows:

- a. Divide the work of a man performing any job into simple elementary movements.
- b. Pick out all useless movements and discard them.
- c. Study, one after another, just how each of several skilled workmen makes each elementary movement, and with the aid of a stop watch select the quickest and best method of making each elementary movement known in the trade.
- d. Describe, record, and index each elementary movement, with its proper time, so that it can be quickly found.
- e. Study and record the percentage which must be added to the actual working time of a good workman to cover unavoidable delays, interruptions, minor accidents, etc.
- f. Study and record the percentage which must be added to cover the newness of a good workman to a job, the first few times that he does it. (This percentage is quite large on jobs made up of a large number of different ele-

<sup>1</sup> Subcommittee on Administration of the A.S.M.E., "The Present State of the Art of Industrial Management," *Transactions of the A.S.M.E.*, Vol. 34, pp. 1197-1198, 1912.

<sup>2</sup> *Ibid.*, pp. 1199-1200.



ments composing a long sequence infrequently repeated. This factor grows smaller, however, as the work consists of a smaller number of different elements in a sequence that is more frequently repeated.)

- g.* Study and record the percentage of time that must be allowed for rest, and the intervals at which the rest must be taken, in order to offset physical fatigue.

The constructive work of time study is as follows:

- h.* Add together into various groups such combinations of elementary movements as are frequently used in the same sequence in the trade, and record and index these groups so that they can be readily found.
- i.* From these several records, it is comparatively easy to select the proper series of motions which should be used by a workman in making any particular article and, by summing the times of these movements and adding proper percentage allowances, to find the proper time for doing almost any class of work.
- j.* The analysis of a piece of work into its elements almost always reveals the fact that many of the conditions surrounding and accompanying the work are defective; for instance, that improper tools are used, that the machines used in connection with it need perfecting, and that the sanitary conditions are bad, etc. And knowledge so obtained leads frequently to constructive work of a high order, to the standardization of tools and conditions, to the invention of superior methods and machines.

From the above definition it is apparent that Taylor made some use of motion study as a part of his time study technique. However, he placed greater emphasis on materials, tools, and equipment in connection with the improvement of methods. It remained for the Gilbreths to develop motion study as we know it today.

As important as is Taylor's contribution in originating time study, this is only one of his many achievements. To him also goes the credit for inventing high-speed steel, discovering and evaluating the variables affecting the cutting of metals, originating the functional type of organization, and developing a system or philosophy commonly referred to as scientific management. These achievements were not accidental, but the result of a systematic study of the factors affecting the problem in each instance. Taylor's real contribution to industry was his scientific method, his substitution of fact-finding for rule-of-thumb procedure. His questioning attitude and his constant search for the facts gave him the high place which he reached and still holds as a proponent of science in management. He was a pioneer in applying science to that phase of industry which intimately affected the worker. He understood that he was dealing with a human problem as well as with materials and machines, and he approached the human



side of his investigations with an understanding of its psychological aspects.<sup>3</sup>

So great has been Taylor's contribution to the whole problem of effective utilization of human effort in industry that we can profit from a review of some of his work in this field. Taylor came from a well-to-do Philadelphia family, was trained at Phillips Exeter Academy to enter Harvard, and after but a year and a half at Phillips Exeter passed the Harvard entrance examinations with honors but at the cost of seriously impaired eyesight. Forced to give up the idea of further study, at the age of eighteen he obtained a job in a machine shop where he served the apprenticeships of machinist and pattern-maker. In 1878, when he was twenty-two, he went to work at the Midvale Steel Works. As business conditions were bad at that time, he took a job as an ordinary laborer. He was rapidly promoted to time clerk, journeyman, lathe operator, gang boss, foreman of the machine shop, and at the age of thirty-one was made chief engineer of the works. During his early years at Midvale, Taylor studied at night and in 1883 obtained a degree in mechanical engineering from Stevens Institute.

**Taylor's Principles of Management.** It was as gang boss and foreman that Taylor first came face to face with such problems as "Which is the best way to do this job?" "What should constitute a day's work?" and problems of a similar nature. Taylor, being very conscientious himself, expected the men under him to do a fair day's work. He set for himself the task of finding the proper method of doing a given piece of work, teaching the worker how to do it in this way, maintaining all conditions surrounding the work so that the worker could do the task properly, setting a definite time standard for accomplishing the work, and then paying the worker a premium in the form of extra wages for doing the task as specified. Many years later Taylor explained his objectives in the following way:

First. The development of a science for each element of a man's work, thereby replacing the old rule-of-thumb methods.

<sup>3</sup> Some maintain that Taylor merely tried to squeeze more work from the employees and that his methods were not scientific. For objections to Taylor's methods, see:

(a) R. F. Hoxie, "Scientific Management and Labor," D. Appleton & Co., New York, 1915.

(b) Symposium—"Stop-Watch Time Study, an Indictment and a Defense," *Bulletin of the Taylor Society*, Vol. 6, No. 3, pp. 99-135, June, 1921.

(c) E. Farmer, "Time and Motion Study," Industrial Fatigue Research Board, *Report 14*, H. M. Stationery Office, London, 1921.



Second. The selection of the best worker for each particular task and then training, teaching, and developing the workman; in place of the former practice of allowing the worker to select his own task and train himself as best he could.

Third. The development of a spirit of hearty cooperation between the management and the men in the carrying on of the activities in accordance with the principles of the developed science.

Fourth. The division of the work into almost equal shares between the management and the workers, each department taking over the work for which it is the better fitted; instead of the former condition, in which almost all of the work and the greater part of the responsibility were thrown on the men.<sup>4</sup>

Taylor stated many times that scientific management required "a complete mental revolution on the part of the workman—and on the part of those on management's side."<sup>5</sup> "Both sides must recognize as essential the substitution of exact scientific investigation and knowledge for the old individual judgment or opinion."<sup>6</sup>

Although Taylor realized that there was more to the management of an industrial enterprise than conducting investigations on methods of doing work, he stated in no uncertain terms that one of the first duties of management was "to develop a science for each element of a man's work" and he used and advocated the scientific approach in the solution of every problem that arose in this connection.

Mr. Eric Farmer of Great Britain, in a most critical analysis of Taylor's work, states, "Taylor's greatest and lasting contribution to the science of industry is the method he adopted. He approached problems which had been thought either not to exist or to be easily solved by common sense, in the spirit of scientific enquiry."<sup>7</sup>

During his many years in industry Taylor carried on extended investigations in order to determine the best way to do work and to obtain specific data for standardizing the task. In order to illustrate his approach, one of his well-known studies will be briefly described here.

**Taylor's Investigation of Shoveling.** In 1898, when Taylor went to the Bethlehem Steel Works, he undertook to improve methods in various parts of the plant. One task that came to his attention was shoveling. Four hundred to 600 men were employed in the yard, and much of their work was shoveling. More iron ore was shoveled than

<sup>4</sup> F. W. Taylor, "The Principles of Scientific Management," p. 36, Harper & Bros., New York, 1929.

<sup>5</sup> F. B. Copley, "Frederick W. Taylor," Vol. I, p. 10, Harper & Bros., New York, 1923.

<sup>6</sup> *Ibid.*, p. 12.

<sup>7</sup> E. Farmer, "Time and Motion Study," Industrial Fatigue Research Board, Report 14, H. M. Stationery Office, London, 1921.



any other material, and rice coal came next in tonnage. Taylor found that each good shoveler in that yard owned his own shovel; he preferred to do this rather than to have the company furnish it. A foreman supervised 50 to 60 men, and they shoveled a variety of material in the course of a day. The yard was approximately two miles long and a quarter of a mile wide, so that the gang moved about over a large area.

With little investigation Taylor found that shovelers were lifting loads of  $3\frac{1}{2}$  pounds when handling rice coal and up to 38 pounds to the shovel when moving ore. He immediately set about to determine what shovel load permitted a first-class shoveler to move the most material in a day. Taylor took two good shovelers and set them to work in different parts of the yard and set two time study men with stop watches to study the work of these men. At first large shovels were used so that heavy loads were taken. Then the end of the shovel was cut off to permit a smaller shovel load and again the tonnage handled was noted. This procedure was continued—from very heavy shovel loads to very light ones. The results of this study showed that, with a load of  $21\frac{1}{2}$  pounds on the shovel, a man could handle a maximum tonnage of material in a day. Thus, a small spade-shovel that would just hold  $21\frac{1}{2}$  pounds was provided for the worker when he handled ore and a large scoop was provided for light material, such as ashes.

A tool room was established, and special shovels were purchased and issued to the workers as needed. In addition Taylor inaugurated a planning department to determine in advance the work to be done in the yard. This department issued orders to the foremen and the workers each morning, stating the nature of the work to be done, the tools needed, and the location of the work in the yard. Instead of the men working together in large gangs, the material handled by each man was measured or weighed at the end of the day, and each man was paid a bonus (60 per cent above day wages) when he did the specified amount of work. If a man failed to earn the bonus, an instructor was sent out to show the worker how to do his job in the proper way and so earn the bonus.

After  $3\frac{1}{2}$  years at the Bethlehem plant Taylor was doing the same amount of work in the yards with 140 men as was formerly done by 400 to 600. He reduced the cost of handling material from 7 to 8 cents to 3 to 4 cents per ton. After paying for all added expenses, such as planning the work, measuring the output of the workers, determining and paying bonuses each day, and maintaining the tool room, Taylor



still showed a saving during the last six-month period at the rate of \$78,000 per year.<sup>8</sup>

One cannot read Taylor's experiments on the art of cutting metals,<sup>9</sup> his study of rest pauses in handling pig iron,<sup>10</sup> or his investigations in shoveling without at once realizing that he was a scientist of high order. With Taylor, as with the factory manager today, time study was a tool to be used in increasing the overall efficiency of the plant, making possible higher wages for labor, and lower prices of the finished products to the consumer.

#### MOTION STUDY AS IT WAS DEVELOPED BY THE GILBRETHS

Motion study cannot be discussed without constant reference to the work of Frank B. Gilbreth and his wife, Lillian M. Gilbreth. Industry owes a great debt to them for their pioneering work in this field. The fundamental character of their work is indicated by the fact that the principles and techniques which they developed many years ago are being adopted by industry today at an increasingly rapid rate.

The story of the work of the Gilbreths is a long and fascinating one. Mrs. Gilbreth's training as a psychologist and Mr. Gilbreth's engineering background fitted them in a unique way to undertake work involving an understanding of the human factor as well as a knowledge of materials, tools, and equipment. Their activities cover a wide range including noteworthy inventions and improvements in building and construction work,<sup>11</sup> study of fatigue,<sup>12</sup> monotony,<sup>13</sup> transfer of skill, and work for the handicapped,<sup>14</sup> and the development of such techniques as the process chart, micromotion study, and the chronocyclegraph.

In this book particular attention is given to their work dealing with the process chart, motion study, and micromotion study.

<sup>8</sup> F. B. Copley, "Frederick W. Taylor," Vol. II, p. 56, Harper & Bros., New York, 1923.

<sup>9</sup> F. W. Taylor, "On the Art of Cutting Metals," *Transactions of the A.S.M.E.*, Vol. 28, Paper 1119, pp. 31-350, 1907.

<sup>10</sup> Copley, *op. cit.*, p. 37.

<sup>11</sup> F. B. Gilbreth, "Motion Study," D. Van Nostrand Co., New York, 1911.

<sup>12</sup> F. B. and L. M. Gilbreth, "Fatigue Study," Macmillan Co., New York, 1919.

<sup>13</sup> L. M. Gilbreth, "Monotony in Repetitive Operations," *Iron Age*, Vol. 118, No. 19, p. 1344, Nov. 4, 1926.

<sup>14</sup> F. B. and L. M. Gilbreth, "Motion Study for the Handicapped," George Routledge Sons, London, 1920.



**The Beginning of Motion Study.** In 1885, Gilbreth, as a young man of seventeen, entered the employ of a building contractor. In those days brick construction constituted an important part of most structures, so Gilbreth began by learning the bricklayer's trade. Promotions came rapidly, and by the beginning of the century Gilbreth was in the contracting business for himself. From the very beginning of his connection with the building trades Gilbreth noted that each craftsman used his own peculiar methods in doing his work, and that no two men did their work in exactly the same way. Furthermore, he observed that the worker did not always use the same set of motions. The bricklayer, for example, used one set of motions when he worked rapidly, another set of motions when he worked slowly, and still a third set when he taught someone else how to lay brick.<sup>15</sup> These observations led Gilbreth to begin investigations to find the "one best way" of performing a given task. His efforts were so fruitful and his enthusiasm for this sort of thing became so great that in later years he gave up his contracting business entirely in order to devote his entire time to motion study investigations and applications.<sup>16</sup>

It was apparent from the beginning that Gilbreth had a knack for analyzing the motions used by his workmen. He readily saw how to make improvements in methods, substituting shorter and less fatiguing motions for longer and more tiring ones. He made photographs of bricklayers at work, and from a study of these photographs he continued to make progress in bringing about increased output among his workers. For example, Gilbreth invented a scaffold which could quickly and easily be raised, a short distance at a time, thus permitting it to be kept near the most convenient working level at all times. This scaffold was also equipped with a bench or shelf for holding the brick and mortar at a convenient height for the workmen. This saved the bricklayer the tiring and unnecessary task of bending over to pick up a brick from the floor of the scaffold each time he laid one on the wall.

Formerly, brick were dumped in a heap on the scaffold and the bricklayer selected the brick as he used them. He turned or flipped the brick over in his hand in order to find the best side to place on the face of the wall. Gilbreth improved this procedure. As the brick

<sup>15</sup> L. M. Gilbreth, "The Quest of the One Best Way," p. 16, a sketch of the life of F. B. Gilbreth published by Mrs. Gilbreth, 1925.

<sup>16</sup> John G. Aldrich. See discussion of Gilbreth's work at the New England Butt Company. "The Present State of the Art of Industrial Management," *Transactions of the A.S.M.E.*, Vol. 34, Paper 1378, pp. 1182-1187, 1912.



were unloaded from the freight car, Gilbreth had low-priced laborers sort them and place them on wooden frames or "packets" 3 feet long. Each packet held 90 pounds of brick. The brick were inspected by these men as they unloaded them. They were then placed on the packet, side by side, so that the best face and end were uniformly turned in a given direction. The packets were next placed on the scaffolds in such a way that the bricklayer could pick up the brick quickly without having to disentangle them from a heap. Gilbreth had the mortar box and the packets of brick arranged on the scaffold in such relative positions that the bricklayer could pick up a brick with one hand and a trowel full of mortar with the other at the same time. Formerly, the bricklayer in reaching down to the floor to pick up a brick with one hand permitted the other hand to remain idle.

In addition, Gilbreth arranged for the mortar to be kept of the proper consistency so that the brick could be shoved into place on the wall with the hand. This eliminated the motion of tapping the brick into place with the trowel. These changes, along with others which Gilbreth developed, greatly increased the amount of work which a bricklayer could do in a day. For example, in exterior brickwork, using the "pick and dip" method, the number of motions required to lay a brick were reduced from 18 in the old method to  $4\frac{1}{2}$  in the new method.<sup>17</sup>

On a particular building near Boston, on a 12-inch brick wall with drawn joints on both sides and of two kinds of brick, which is a rather difficult wall to lay, bricklayers were trained in the new method. By the time the building was a quarter to a half of the way up, the average production was 350 bricks per man per hour. The record for this type of work previous to the adoption of the new system had been but 120 bricks per man per hour.<sup>18</sup>

**Definition of Micromotion Study.** Although Gilbreth was aided greatly in his motion study investigations by photographs which he made of his workers in motion, it was not until he adapted the motion-picture camera to his work that he made his greatest contribution to industrial management. In fact, the technique of micromotion study as he and Mrs. Gilbreth developed it was made possible only through the use of motion pictures.

<sup>17</sup> F. B. Gilbreth, "Motion Study," p. 88, D. Van Nostrand Co., New York, 1911.

<sup>18</sup> "Taylor's Famous Testimony before the Special House Committee," *Bulletin of the Taylor Society*, Vol. 11, No. 3 and No. 4, p. 120, June-August, 1926.



The term micromotion study was originated by the Gilbreths, and the technique was first made public<sup>19</sup> at a meeting of the American Society of Mechanical Engineers in 1912. A brief explanation of micromotion study might be given in this way: Micromotion study is the study of the fundamental elements or subdivisions of an operation by means of a motion-picture camera and a timing device which accurately indicates the time intervals on the motion-picture film. This, in turn, makes possible the analysis of the elementary motions recorded on the film and the assignment of time values to each.

The Gilbreths made little use of stop-watch study. In fact, concentrating on finding the very best way for doing work, they wished to determine the shortest possible time in which the work could be performed. They used timing devices of great precision and selected the best operators obtainable as subjects for their studies.

**The Chronocyclegraph.** Gilbreth developed still another technique, which he called the chronocyclegraph, for the study of motions. A description of this is given here.

It is possible to record the path of motion of an operator in three dimensions by attaching a small electric light bulb to the finger, hand, or other part of the body and photographing, with a stereoscopic camera, the path of light as it moves through space. Such a record is called a cyclegraph.<sup>20</sup>

If an interrupter is placed in the electric circuit with the bulb, and if the light is flashed on quickly and off slowly, the path of the bulb will appear as a dotted line with pear-shaped dots indicating the direction of the motion. The spots of light will be spaced according to the speed of the movement, being widely separated when the operator moves fast and close together when the movement is slow. From this graph it is possible to measure accurately time, speed, acceleration, and retardation; and to show direction and the path of motion in three dimensions. Such a record is called a chronocyclegraph. From the chronocyclegraph it is possible to construct accurate wire models of the motion paths. Gilbreth used these to aid in improving methods, to demonstrate correct motions, and to assist in teaching new operators.

**The Narrower Interpretation of Time Study Is Rapidly Passing.** If the development of time study and of motion study is followed

<sup>19</sup> F. B. Gilbreth. See his discussion in "The Present State of the Art of Industrial Management," *Transactions of the A.S.M.E.*, Vol. 34, pp. 1224-1226, 1912.

<sup>20</sup> F. B. and L. M. Gilbreth, "Applied Motion Study," p. 73, Sturgis and Walton Co., New York, 1917.



carefully and in some detail, it is not difficult to understand how these two terms came to be interpreted by some as having widely different objectives. One group saw time study only as a means of setting rates, using the stop watch as the timing device.<sup>21</sup> Another group saw motion study only as an expensive and elaborate technique, requiring a motion-picture camera and laboratory procedure for determining a good method of doing work. At the same time, still others more readily took the best from the work of both Taylor and Gilbreth and, with a proper sense of proportion, used the methods and the devices that seemed to be most applicable to the solution of the particular problem at hand.

Today the controversy between the value of using either the one or the other of the two techniques has largely passed, and industry has found that time study and motion study are inseparable, as their combined use in many factories and offices demonstrates. With the increasing use of both time study and motion study, and with the growing belief that the two are dependent upon each other, there has come a desire on the part of many for a single term with which to designate the whole subject. Some have suggested "operation study," "job standardization," "time and motion study," "methods study," "job study," and "motion and time study." Of these terms the last seems to be the most logical, the most accurate, and the one that most nearly interprets the present practice in this field. It also has the desirable feature of lending itself to the broad meaning which some of the other terms do not have.

In consideration of the developments in this field since the time of Taylor and in consideration of the present trends, it seems best to use motion and time study in the sense explained in the preceding chapter.

<sup>21</sup> L. M. Gilbreth, "The Psychology of Management," p. 106, Sturgis & Walton Co., New York, 1914.



## CHAPTER 3

### EXTENT TO WHICH MOTION AND TIME STUDY MAY BE PROFITABLY USED

Having outlined the scope of motion and time study and having indicated the several techniques that may be employed, the next step is to determine where and to what extent these several procedures may be used to best advantage.

The problem is parallel to that of selecting a device for measuring length. The carpenter framing a house would need no more accurate scale than his two-foot rule, whereas the machinist grinding a steel shaft would require an accurate micrometer, and the tool maker building a master gauge for the most accurate work in the manufacture of automobile motor parts would need precision gauge blocks as his measuring device. Each of these three devices has its place in the measurement of length, and in a similar manner each of the several techniques has its place in motion and time study work.

Every job investigated will not require all the refinements that motion and time study has to offer. Some classes of work will justify a thorough analysis; others will not warrant such an expenditure of time. The more extensive the study, the greater the amount of time required to make it. Only such expense should be incurred in investigating an operation or a process as will be economically justified. A long-time point of view should be taken in evaluating certain phases of motion and time study work. For example, it is not advisable to curtail a study to the extent that it is impossible to obtain accurate and dependable time standards and satisfactory standard practice records.

**Motion and Time Study Techniques.** The objects of motion and time study may be achieved in a number of different ways. There are many combinations of the various techniques that may be used, and each of them will be described fully in succeeding chapters. It seems convenient to list in tabular form (see Table I) five combinations that are very frequently used in motion and time study applications. They range from the most complete, Type A, on the left, to the simplest, Types D and E, on the right.



TABLE I  
COMBINATIONS OF MOTION AND TIME STUDY TECHNIQUES

Type	A	B	C	D	E
Finding the most economical way of performing the operation a. Methods b. Materials c. Tools and equipment d. Working conditions	Process analysis	Process analysis	Process analysis	.....	.....
	Full micromotion study of operation	Motion study Detailed analysis by therbligs	Motion study Detailed analysis of elements	Motion study Cursory analysis	Motion study Cursory analysis
	Application of motion-economy principles	Application of motion-economy principles	Application of motion-economy principles	Application of motion-economy principles	Application of motion-economy principles
	Standardization of the operation	Standardization of the operation	Standardization of the operation	Standardization of the operation	Standardization of the operation
Standardizing the: a. Methods b. Materials c. Tools and equipment d. Working conditions	Written standard practice Instruction sheet Motion-picture record of improved method	Written standard practice Instruction sheet	Written standard practice or Instruction sheet	Written standard practice or Instruction sheet	Written standard practice or Instruction sheet (standardized for each class of work)
	1. Stop-watch study 2. Micromotion study 3. Standard time data a. For certain therbligs b. For certain elements 4. Complete standard-time data 5. Formulas	1. Stop-watch study 2. .... 3. Standard-time data a. For certain therbligs b. For certain elements 4. Complete standard-time data 5. Formulas	1. Stop-watch study 2. .... 3. .... 4. .... 5. ....	1. Stop-watch study 2. .... 3. .... 4. .... 5. ....	1. .... 2. .... 3. .... 4. Complete standard-time data 5. Formulas
Determining the time standard	In separate training department or at work place	In separate training department or at work place	.....	.....	.....
	Motion pictures Instruction sheets	..... Instruction sheets	..... Instruction sheets	..... Instruction sheets	..... Instruction sheets (standardized for each class of work)
Training the operator					
Applying the wage incentive					

This is not a part of motion and time study but usually accompanies it.



There are four principal factors which determine the combination of motion and time study techniques to be used. They are:

1. The extensiveness of the job, that is, the average number of man-hours per day or per year used on the work.
2. The anticipated life of the job.
3. Labor considerations of the operation, such as:
  - (a) The hourly wage rate
  - (b) The ratio of handling time to machine time
  - (c) Special qualifications of the employee required, unusual working conditions, labor union requirements, etc.
4. The investment in the machines, tools, and equipment required for the job.

#### **An Example of the Most Refined Use of Motion and Time Study.**

The Type A study would include an analysis of the process and the construction of a process chart of the entire manufacturing process of which the operation under consideration is a part. It would require a full micromotion study and the application of the principles of motion economy which would include a consideration of the most economical use of materials, tools, and equipment, and the provision for satisfactory working conditions. After the most economical way of doing the work has been found it would be standardized and a standard practice record would be prepared. It might also involve the making of motion pictures of the old and of the improved method. A time standard would then be set by means of stop-watch study, or from data taken from the micromotion study, or from standard data already available. The Type A study would also provide for the training of the operator, either in a separate training department or at the work place and with the aid of motion pictures and instruction sheets. The time study would more than likely be followed by the application of a wage incentive to the job.

An example will be given to show where a Type A study would be used. The job is a semi-automatic lathe operation. The data for this operation, tabulated under the four headings listed above, would appear as follows:

1. More than 100 girls are employed on this operation. They work an 8-hour day, 40-hour week, and 50-week year which gives 200,000 man-hours per year.
2. The job is a permanent one. This operation has been performed for many years, and it is expected that it will be continued indefinitely.



3. Female labor is used.

- (a) The basic hourly wage is \$0.90 per hour. A 100 per cent premium plan of wage payment is used. Standards are set by stop-watch study and the hourly wage is guaranteed.
- (b) Each cycle requires 0.25 minute, of which approximately 60 per cent is handling time and 40 per cent is machine time.
- (c) Because special skill is required to perform this operation, each new operator is given 6 weeks of special training in a separate training department. Working conditions are normal.

4. The special semi-automatic lathe, fully equipped, costs approximately \$1500.00 when new.

It is apparent that this operation has great potential savings. The fact that 100 girls are employed on this single operation and that more than 50 million units are produced annually would at once indicate a Type A study. In fact, for every hundredth of a minute saved per piece on this operation there would be a saving to the company in direct labor cost of over \$7000.00 per year.

**An Example of the Simplest Use of Motion and Time Study.** On the other extreme are the Type D and the Type E motion and time studies. These are alike except that the Type E is used where an entire class of work has been previously standardized and where only sufficient analysis need be made to determine into what subdivision a given operation falls. The Type D study would be made on operations of short duration, and with little prospect for improvements. This study would involve but a cursory analysis and a very general application of the principles of motion economy, a written standard practice, a time standard set by a stop-watch time study, and an instruction sheet prepared to aid in training the operator. A wage-incentive application would more than likely be used after the motion and time study.

A Type D study would be used on the following job. The operation is drilling and counterboring a small bracket on a sensitive drill press. The job requires the time of one man for 10 days per month. The operation is expected to last for 6 months, when the model will be changed. The operator is paid \$1.05 per hour. In this case a cursory analysis would include a check of the drill speeds, the arrangement of the tote boxes, location of the jig and air hose, and other similar factors. Only a few hours would be required for the analysis



and for the execution of the recommended changes. For every hundredth of a minute saved per piece on this operation there would be a saving to the company in direct labor cost of less than \$20.00 per year. A stop-watch time study would be made and a wage incentive would probably be applied.

The time required for making the Type D study described above would be short and the cost would be small, whereas months would be required for study of the semi-automatic lathe operation and considerable expense would be involved.

Types A and B studies are used either for individual jobs or for classes of similar work; Types C and D studies are used primarily for individual jobs. In some plants there are many short operations of similar nature which in themselves would warrant only a Type D study, but when considered together as a class would justify the use of a Type A or B study.

The Type E study is used for individual jobs within classes or families, for jobs of a similar nature, and for work already standardized. This type would largely involve the selection of necessary information from standard data on file. Chapter 24 gives an example of such a class of work, that is, hobbing teeth on straight spur gears. The methods, tools, equipment, and working conditions have been standardized. By means of standard-time data and the use of formulas it is possible to determine time standards synthetically for such work. Instruction sheets are prepared by filling in the necessary machine time (see italics in Fig. 291 on page 483) on standard forms.<sup>1</sup>

<sup>1</sup> For additional material on the extent to which motion and time study should be used, see: H. B. Maynard, "Methods Engineering Installation: Mapping Out the Program," *Modern Machine Shop*, Vol. 9, pp. 62-70, July, 1936, and pp. 46-52, August, 1936.



## CHAPTER 4

### DEVELOPING A BETTER METHOD

The first step in developing a better and easier work method is to get an accurate picture of the present method. This picture may be obtained by making a list of all the details in the process. It is important to have a bird's-eye view of the work from start to finish. It is desirable even though the job singled out for special study involves but one operation in the process. The simplest form of work analysis consists of taking a sheet of paper and listing in sequence all the steps in the process.

After a careful record of the entire process has been made, a similar breakdown should be made of each operation in the process, starting with the most important operation first, that is, the operation that has the greatest potential savings. For example, suppose we consider the process of bottling milk in a small dairy plant. The overall picture would show the unloading of empty milk bottles from the delivery truck at the milk plant, then washing the bottles, removing washed bottles from the washing machine, inspecting the bottles, filling and capping the bottles, moving filled bottles to the cold room, and finally removing the cases of full milk bottles to the delivery truck.

In addition to this overall analysis, a detailed breakdown of each operation in the process might also be made. If washing empty bottles required the greatest number of man-hours and if the method in use seemed particularly inefficient, that operation should be studied first.

It is fairly easy to record the steps used in a process, and it is likewise a rather simple task to make a breakdown of the operations involved. The real problem is to make changes that will result in a better, easier, and safer method of doing the work.

**Question Everything about the Job.** One of the best ways to approach the problem of methods improvement is to question everything about the job—the *way* the job is being done now, the *materials* that are being used, the *tools* and *equipment*, the *working conditions*, and even the *design* of the product. Assume that nothing about the job is perfect.



As the process chart or flow diagram is being made every item that is put down on the chart should be questioned. Begin by asking the questions What? Why? Who? Where? When? How?

1. *What* is done? What is the purpose of the operation?
2. *Why* is the work done? What would happen if it were not done? Is every part of the job necessary?
3. *Who* does the work? Who could do it better? Can changes be made to permit a person with less skill and training to do the work?
4. *Where* is the work done? Could it be done somewhere else more economically?
5. *When* is the work done? Would it be better to do it at some other time?
6. *How* is the work done? This suggests a careful analysis and the application of the principles of motion economy.

**Analyze the Work—Develop a Better Method.** After all phases of the work have been subjected to the above questions, consider the following possibilities for job improvement:

- A. Eliminate all unnecessary work.
- B. Combine operations or elements.
- C. Change the sequence of operations.
- D. Simplify the necessary operations.

Each of these four approaches to the development of better methods will be discussed more fully here.

**A. Eliminate All Unnecessary Work.** The very first question that should be asked about any job is why do it at all? Can it be eliminated? The *what* and *why* questions are the pertinent ones here. These questions should be asked about each transportation, storage, delay, and inspection as well as about every operation in the entire process.

It is obvious that if the job in question can be eliminated that particular problem is solved. No effort should be wasted in trying to combine elements, change the sequence, or simplify the method if the operation, or a part of it, can be dispensed with. We all know of many commonplace illustrations of unnecessary operations. The use of the window envelope makes it unnecessary to address the envelope; placing the address on the magazine itself makes it unnecessary to use a wrapper or mailing envelope. The carton for milk replaces



the bottle and eliminates the work of handling and washing empty milk bottles in the kitchen and in the milk plant.

**B. Combine Operations or Elements.** Although it is customary to break down a process into many simple operations, in some instances the division of labor has been carried too far. It is possible to subdivide a process into too many operations, causing excessive handling

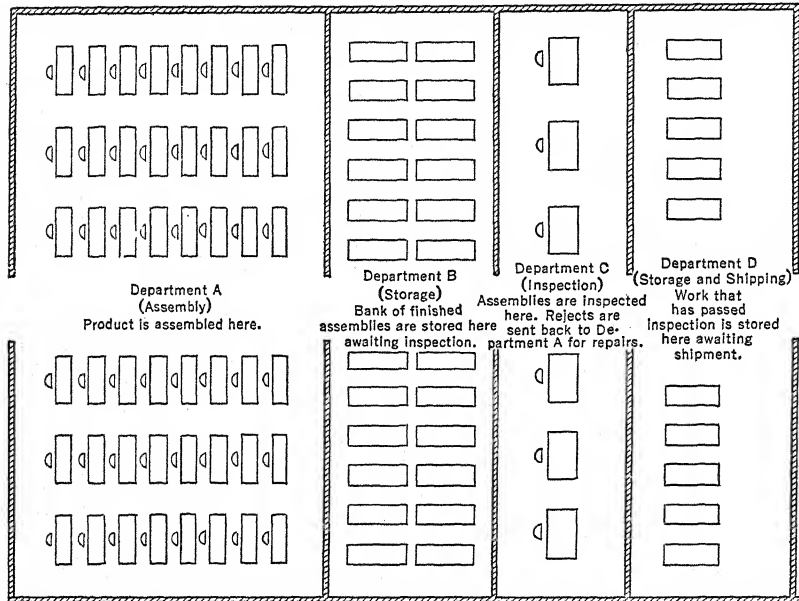


FIG. 3. Layout of building for assembly and inspection of small parts produced on semi-automatic machines—old arrangement of departments. Notice that inspection was done in Department C.

of materials, tools, and equipment. Also such problems as the following may be created: difficulty in balancing the many operations; accumulation of work between operations when improper planning exists; and delays when inexperienced operators are employed or when operators are off the job. Thus it is sometimes possible to make the work easier by simply combining two or more operations or by making some changes in method permitting operations to be combined.

**C. Change the Sequence of Operations.** When a new product goes into production it frequently is made in small quantities on an "experimental" basis. Often production increases gradually, and in time output becomes large, but the original sequence of operations may be kept the same as when production was small. For this and other rea-



sons it is desirable to question the order in which the different operations are performed.

For example, in one plant small assemblies were made on semi-automatic machines in Department A. (See Fig. 3.) They were stored in Department B, inspected in Department C, and packed for shipment in Department D. The manufacturing methods were such

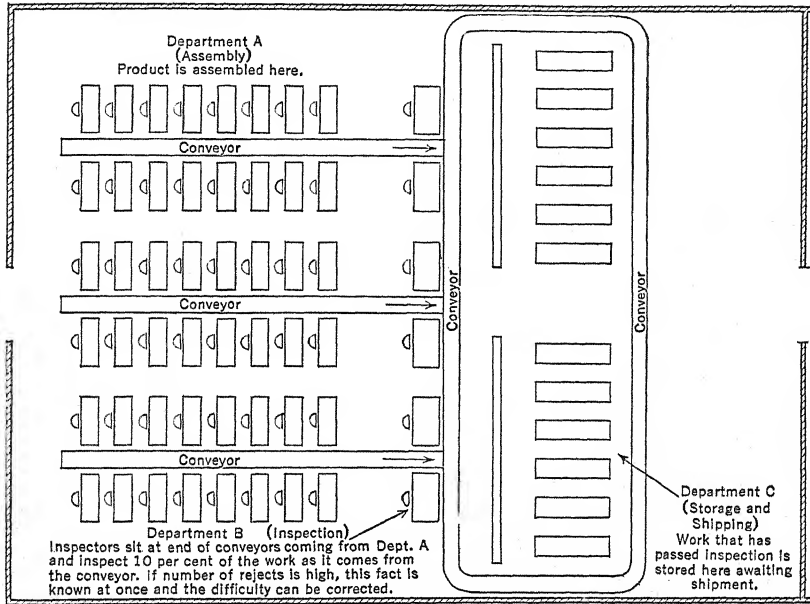


FIG. 4. Layout of building for assembly and inspection of small parts—improved arrangement of departments. Inspection now takes place immediately adjacent to the assembly department.

that normally only 10 per cent of the finished assemblies were inspected. When an excessive number of defects were found, however, then all work was given a 100 per cent inspection until the cause of the trouble was found and corrected.

Since there was always a bank of several days' work in Department B awaiting inspection, when trouble was encountered it was necessary to give this entire bank of work a 100 per cent inspection, and moreover defective assemblies had to be repaired or scrapped. To correct this difficulty the inspectors were placed immediately adjacent to the assembly department, and the bank of finished assemblies awaiting inspection was eliminated as shown in Fig. 4. Since each unit was inspected as it came from the assembly line, rejects were found in a



few minutes after the units were completed, and the cause of the difficulty could be corrected before other "scrap" parts had been made. This simple rearrangement, which was easy and inexpensive to make, saved the company tens of thousands of dollars in inspection costs and greatly reduced the number of scrapped parts.

The process chart and flow diagram described in the next chapter serve a useful purpose in pointing out the desirability of changing the sequence of operations to eliminate backtracking, to reduce transportation and handling, and to effect a smooth flow of work through the plant.

**D. Simplify the Necessary Operations.** After the process has been studied and after all improvements that seem worth while have been made, the next step is to analyze each operation in the process and to try to simplify or improve it. In other words, the overall picture is studied first and major changes are made, then the smaller details of the work are studied.

There are several ways to approach the problem of operation analysis and simplification. The first step is to draw a sketch of the work place and list the details of the operation as it is performed now. If the job is not too long or too complex, the motions of the right hand and the left hand may be listed on a sheet of paper, such as the chart in Fig. 51 on page 76. Then using the principles of motion economy (see page 191) as a check list, see if some of them cannot be applied to the job. Question each element or hand motion. Just as in an analysis of the process we tried to eliminate, combine, and rearrange the sequence of operations, so in the single operation we try to eliminate motions, combine them, or rearrange the sequence of necessary motions in order to make the job easier.

**Tools for Methods Improvement.** Before better and easier methods of doing a task can be developed it is necessary to get all the facts pertaining to the job. This involves getting sufficient information to answer the what, why, who, where, when, and how questions as well as to answer satisfactorily the four other questions already suggested. Most people find it useful to list the information in tabular or graphic form. Since several different methods of visualizing a process or an operation have found wide use, each of them will be fully described in the next five chapters. Of course all these different methods would not be used on any one job. For example, it may be found that a process chart or flow diagram is all that is needed. If a single operation is the subject for study, then the operation chart may be used. The activity chart and the man and machine chart are also



useful, and occasionally it may be worth while to make a micromotion analysis of the job, particularly if the cycle is short and if a large number of people are employed on it.

Therefore, it should be clearly understood that the process chart, flow diagram, activity chart, man and machine chart, operation chart, and the simo chart are merely tools to be used as needed.



## CHAPTER 5

### PROCESS ANALYSIS

The entire process of making a part or of doing a piece of work should be studied before undertaking a thorough investigation of a specific operation in the process. Such an overall study will ordinarily include an analysis of each step in the manufacturing process.

**Process Charts.** The process chart is a device for recording, in a compact manner, a process as a means of better understanding it and improving it. The process chart represents graphically the separate steps or events that occur during the performance of a piece of work or during a series of actions. The chart usually begins with the raw material entering the factory and follows it through every step, such as transportation to storage, inspection, machining operations, assembly, until it either becomes a finished unit itself or a part of a sub-assembly. The process chart might, of course, record the process through only one or a few departments.








































A careful study of such a chart, giving a graphic picture of every step in the process through the factory, is almost certain to suggest improvements. It is frequently found that certain operations can be eliminated entirely or that a part of an operation can be eliminated, that one operation can be combined with another, that better routes for the parts can be found, more economical machines used, delays between operations eliminated, and other improvements made, all of which go to produce a better product at a lower cost. The process chart assists in showing the effects that changes in one part of the process will have on other parts or elements. Moreover, the chart may aid in discovering particular operations in the process which should be subjected to more careful analysis. In the office the process chart might show the flow of a time card, material requisition (see Figs. 21 and 23 on pages 42 and 44), purchase order, or any other form through the various steps. The chart might begin with the first entry on the form and show all the steps until the form is finally permanently filed or destroyed.

The process chart may be made profitably by almost any one in an organization. The foreman, supervisor, process and layout engineer,

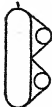


TABLE II

## ORIGINAL GILBRETH PROCESS CHART SYMBOLS

	Stores Requisitioned		Inspection for Quality
	Stores Bought		Inspection for Quantity
	Stores Received		Inspection for Quantity and Quality (Quantity most important)
	Several kinds of Components—Not Desirable to List Individually		Inspection for Quality and Quantity (Quality most important)
	Worked Materials Requisitioned		Over-inspection for Quantity
	Worked Materials Ordered		Over-inspection for Quality
	Worked Materials on Hand		Insp. for Quan. on Exception Principle
	Merchandise in Storage ready to Ship		Insp. for Qual. on Exception Principle
	Storage as part of Process		Over-insp. for Quan. on Exception Principle
	Permanent File of Documents or Materials		Over-insp. for Qual. on Exception Principle
	Temporary File of Documents or Papers		Insp. for Quan. and Oper. performed simultaneously
	Operation Symbol		Insp. for Qual. and Oper. performed simultaneously
	Moved by Operator performing Oper. No. 38		Insp. for Quan. and Qual. and Oper. performed simultaneously. (Quan. most important)
	Moved by Man		Insp. for Qual. and Quan. and Oper. performed simultaneously. (Qual. most important)
	Moved by Boy		
	Moved by Messenger Boy		
	Moved by Elevator		
	Moved by Pneumatic Tube		
	Moved by Conveyor		
	Gravity		
	Belt		
	Moved by Truck		
	Electric Truck		
	Information by Telephone		
	Moved by Mail		

A single Dept. used more than once



— Broken lines indicate process outside of the Dept. Charted  
— used on Dept'l Charts  
— Process within the Department is connected with closed line



as well as the industrial engineer should be familiar with the process chart and should be able to use it.

Many years ago the Gilbreths devised the set of symbols shown in Table II which they used in making process charts.<sup>1</sup> In recent years


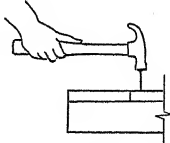
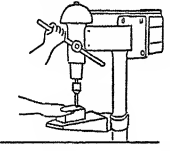
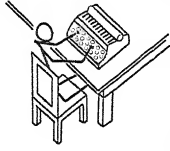


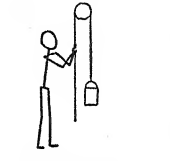




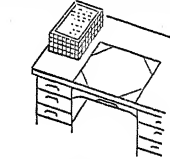


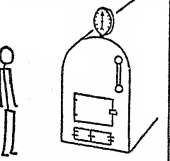
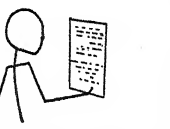
<b>OPERATION</b>  A large circle Indicates an operation, such as →	 Drive nail	 Drill hole	 Type letter
<b>TRANSPORTATION</b>  A small circle Indicates a transportation, such as →	 Move material by truck	 Move material by hoist or elevator	 Move material by carrying (Messenger)
<b>STORAGE OR DELAY</b>  A triangle Indicates a storage or a delay such as →	 Material in truck or on floor at bench waiting to be processed	 Employee waiting for elevator	 Papers waiting to be filed
<b>INSPECTION</b>  A square Indicates an inspection, such as →	 Examine material for quality or quantity	 Read steam gauge on boiler	 Examine printed form for information

Fig. 5. These four process chart symbols save time in recording the steps used in doing work.

the abbreviated set of four symbols shown in the first vertical column of Fig. 5 has been widely used, and they are all that are needed for many kinds of work. These symbols serve as a special sort of shorthand to aid in listing quickly the steps or activities in a process.

<sup>1</sup> F. B. and L. M. Gilbreth, "Process Charts," *Transactions of the A.S.M.E.*, Vol. 43, Paper 1818, pp. 1029-1050, 1921.



The A.S.M.E. standard published last year calls for five symbols<sup>2</sup> as shown in Fig. 6. Perhaps it is not too important which symbols are used in making process charts and flow diagrams. In fact an organization may find that it needs a special set of symbols for its particular needs.<sup>3</sup> Experience shows, however, that where foremen and supervisors are expected to take an active part in developing better methods through process analysis, it is desirable to use as few process chart symbols as possible and charts that are simple to construct and easy to understand.

The process chart symbols used in the illustrations in this volume are shown in Fig. 5 and are described below.

○ *Operation.* A large circle indicates an operation and represents the main steps in the process. The transportations, storages, and inspections are more or less auxiliary to the processing operations. An operation is a subdivision of a process and it is usually performed in one location. Usually a part, material, or product is modified or changed during the operation.

○ *Transportation.* A small circle indicates a transportation. A transportation occurs when the part or object being studied is moved from one place to another. It is often desirable to show the means of transportation by placing a letter inside the circle. For example, (M) = man; (H) = hand truck; (K) = power truck; (C) = conveyor; (E) = elevator; (L) = mail. When the material is stored beside or within 2 or 3 feet of a bench or a machine on which the operation is performed, the movement used in obtaining the material preceding the operation and the movement in disposing of the processed piece to the tote box are considered parts of the operation and not separate transportations. A transportation also occurs when a worker goes from one place to another.

▽ *Storage or Delay.* A triangle indicates a storage or delay. If it seems desirable to differentiate between a temporary storage and a permanent or controlled storage, a P may be placed inside the triangle ▽ or beside the triangle ▽ P to indicate the latter. A storage is con-

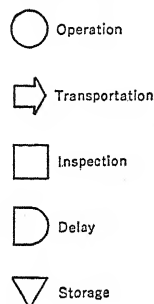


FIG. 6. The A.S.M.E. standard process chart symbols.

<sup>2</sup> "Operation and Flow Process Charts," published by the American Society of Mechanical Engineers, New York, 1947.

<sup>3</sup> Ben S. Graham, "Paperwork Simplification," *Modern Management*, Vol. 8, No. 2, pp. 22-25, February, 1948; Vol. 8, No. 3, pp. 6-10, April, 1948.



sidered a permanent storage when a requisition must be obtained to withdraw it. When the activities of a person rather than those of a part are being charted, the triangle is used to indicate a delay or a wait.

### PROCESS CHART OF WATERING GARDEN

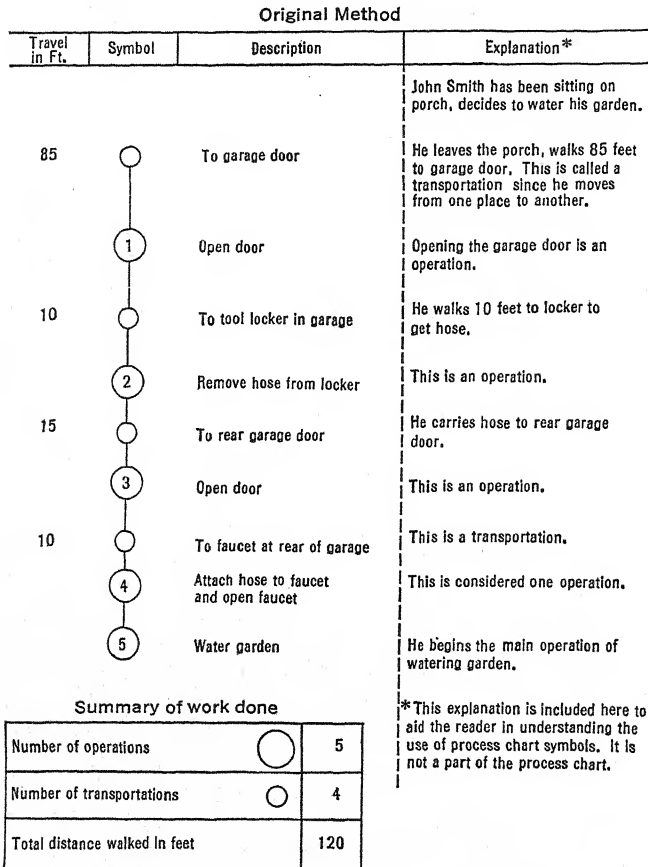



FIG. 7.

This symbol would be used when the individual waits for parts, materials, an elevator, or for another person.

☐ *Inspection.* A square indicates an inspection for either quantity or quality. The quantity inspection may consist of measuring, counting, or weighing. A quality inspection may consist of testing the part to see whether it meets a predetermined standard, and it may also take



the form of grading. Members of the inspection department often do the inspecting, although this may be done by the operator or in some instances by the supervisor.

*Combined Symbols.* Two symbols may be combined when activities are performed at the same work place or when they are performed concurrently as one activity. For example, the large circle within the square  represents a combined operation and inspection.

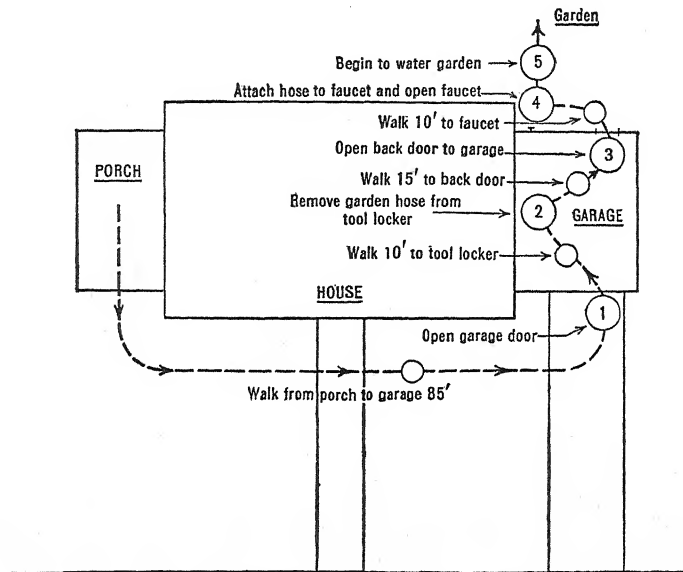


FIG. 8. Flow diagram of watering garden.

The process chart like other methods of graphic representation should be modified to meet the particular situation. The process chart, for example, may show in sequence the activities of a person or it may show in sequence the steps that the material or part goes through. The chart should be either the *man type* or the *material type*, and the two types should not be combined.

**Steps Used in Watering Garden.** In order to illustrate how these symbols may be used, a process chart is shown in Fig. 7 giving the steps used by Mr. Smith in getting ready to water his garden. Mr. Smith, sitting on his porch, decides to water the garden. He leaves the porch, walks to the garage at the other end of the house, opens the garage door, and walks to the tool locker. There he lifts the reel



of garden hose from the locker, carries it to the rear garage door, opens the door, and carries the hose to the faucet at the rear of the garage. He attaches the hose to the faucet, turns on the faucet, and begins to water the garden. An examination of the process chart on the left-hand side of Fig. 7 will show that the use of nine symbols, five numbers, and nine phrases are all that are needed to describe the entire process fully.

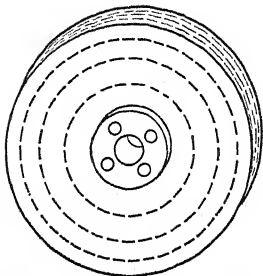


FIG. 9. Buffing wheel.

Sometimes a better picture of the process can be obtained by putting flow lines on a plan drawing of the building or area in which the activity takes place. A sketch of the plan view of the house, lawn, and garden is shown in Fig. 8. Lines are drawn on this sketch to show the path of travel, and the process chart symbols are inserted in the lines to indicate what is taking place. Brief notations are included to amplify the symbols. This is called a flow diagram. Sometimes both a process chart and a flow diagram are needed to show clearly the steps in a manufacturing process, office procedure, or other activity.

#### Re-coating Buffing Wheels with Emery.

In large factories where heavy polishing and buffing operations are required it is

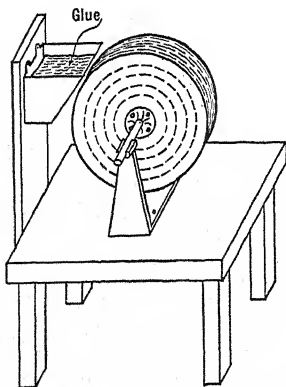


FIG. 10. Operator applies glue to circumference of worn wheel by means of a brush.

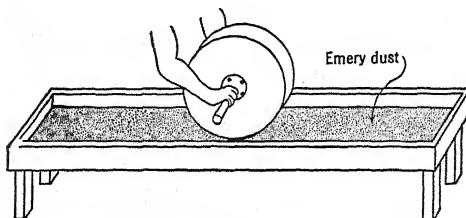


FIG. 11. Old method of re-coating wheel. Operator rolls glue-covered wheel back and forth in trough containing emery dust.

customary to re-coat buffing wheels (see Fig. 9) with emery in the plant and thus keep a supply of fresh wheels always available. In one plow factory, buffing wheels were originally re-coated as described below. The wheels are made of layers of fabric sewed together and the average weight of the wheels is 40 pounds. The wheels vary in diameter



from 18 to 24 inches and in width of face from 3 to 5 inches. The circumference or face of the wheel is coated with glue and emery dust. The first coat of glue is allowed to set approximately one-half hour before the second coat is applied. The temperature in the room where the wheels are cured is maintained between 80 and 90 degrees and the humidity is also controlled.

Originally the method used was to coat the circumference of the worn wheel with glue (see Fig. 10) and then roll the wheel by hand

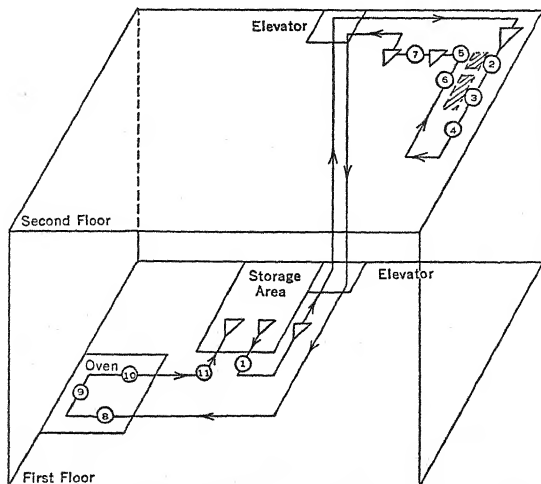


FIG. 12. Flow diagram of old method of re-coating buffing wheels with emery.

through a shallow trough filled with emery dust, thus coating the wheel (see Fig. 11). After the glue had dried, a second coat of glue and emery dust was applied in a similar manner. The wheels were then hauled to a drying oven where they were hung on racks in the oven until the glue was thoroughly dry. Figure 12 shows the flow diagram and Fig. 13 the process chart.

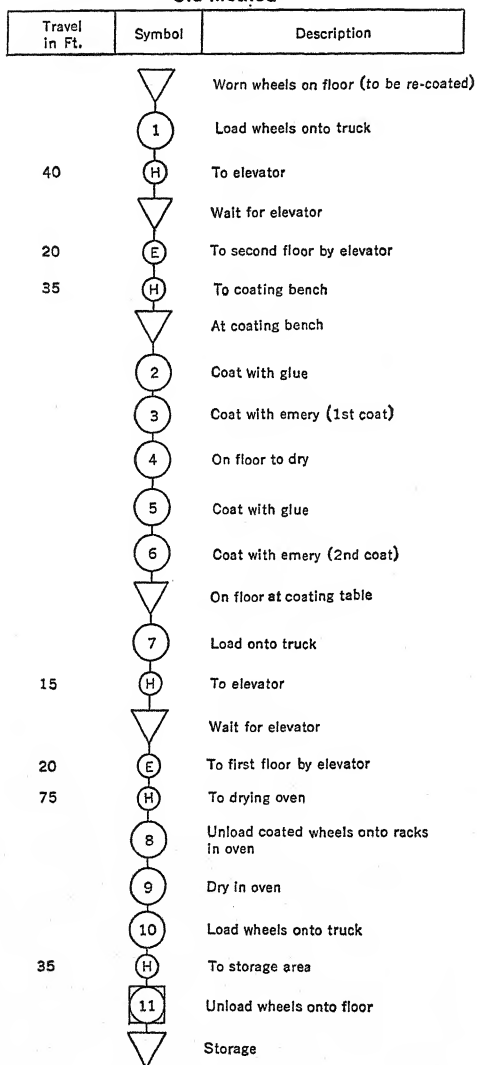
The following questions might be asked about this job: *Why* coat the wheels by hand? *Why* handle the wheels so often? Could the wheels be coated on the first floor instead of on the second? These questions were answered in the following way.

**Improved Method.** A special coating machine (see Fig. 14) was built making it possible to apply the glue and emery to the wheel in one operation with much less time and effort than by the old method. Since this machine was located on the first floor between the storage area and the drying oven (see Fig. 15), it was unneces-



## PROCESS ANALYSIS

**Re-coating Buffing Wheels with Emery  
Old Method**



**Summary**

Number of operations-----○	11
Number of storages and delays--▽	6
Number of inspections-----□	1
Number of transportations-----○	7
Total travel in feet-----	240

Fig. 13. Process chart of old method of re-coating buffing wheels with emery.



sary to move the wheels to the second floor. Special truck-racks (see Fig. 17) were used instead of regular platform trucks, thus eliminating much unnecessary handling of wheels. The coated wheels remained on the truck-racks while in the drying oven. Figure 16 shows the process chart for the improved method as well as a summary of the savings.

*Results.* The new coating machine, the special truck-rack for handling wheels, and the better location of the coating machine re-

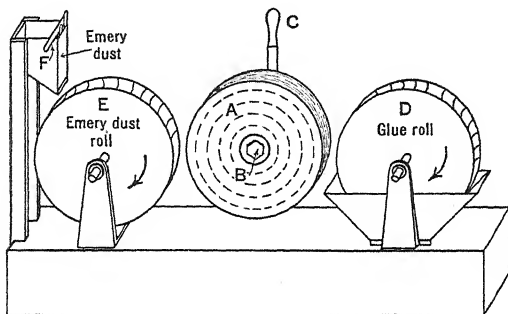


FIG. 14. Schematic drawing showing coating machine. The wheel *A* to be coated is mounted on shaft *B*, which is attached to lever *C*. By swinging lever to right it makes contact with glue roll *D*, which coats circumference of wheel. Lever *C* is then swung to left and makes contact with roll *E*, which coats wheel with emery. Rolls *D* and *E* are both power driven. The lever at *F* controls the amount of emery dust which is fed onto roll *E*.

duced the number of *operations* needed to coat the wheels from 11 to 4, the number of *storages* from 6 to 3, and the *length of travel* from 240 to 70 feet. A crew of four men applied two coats of emery using the old method and their average production was 20 wheels per hour. At the present time a two-man crew applies two coats of emery and their production is 45 wheels per hour. Also the new method of re-coating wheels seemed to improve the quality of the finished wheels because the men using the wheels to grind and polish plowshares have increased their production approximately 25 per cent. The wheels seem to cut faster and make the work easier for the operators.<sup>4</sup>

**Flow Diagram of Feeding Silage on Small Dairy Farm.** Farmers, in increasing numbers, are finding it profitable to apply motion study principles to their work. Real savings are being made on small one-man farms as well as on larger ones. For example, on a 22-cow dairy

<sup>4</sup> This illustration courtesy of James D. Shevlin.



## PROCESS ANALYSIS

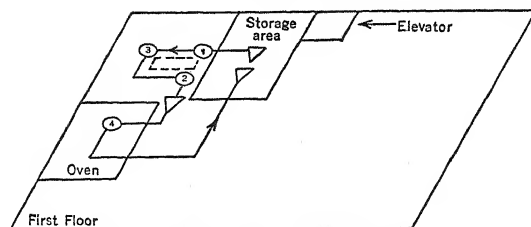
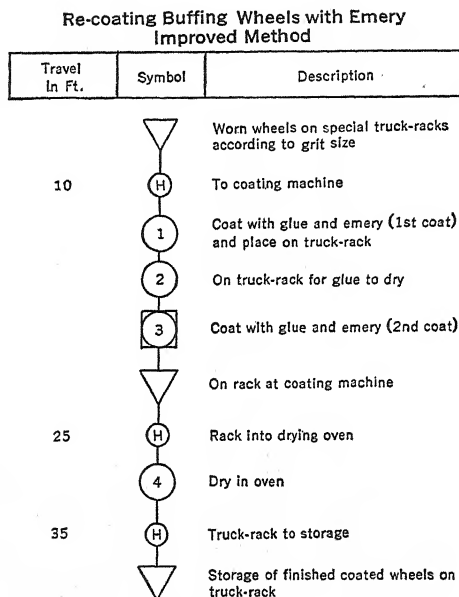


FIG. 15. Flow diagram of improved method of re-coating buffing wheels with emery.



## Summary

	Old Method		Improved Method		Difference	
Number of operations _____ (○)	11		4		7	
Number of storages and delays _____ (▽)	6		3		3	
Number of inspections _____ (□)	1		1		0	
Transportations	No.	Dist.	No.	Dist.	No.	Dist.
By truck _____ (H)	5	200	3	70	2	130
By elevator _____ (E)	2	40	0	0	2	40
Total _____	7	240	3	70	4	170

FIG. 16. Process chart of improved method of re-coating buffing wheels with emery.



farm in Vermont, a systematic study was made of all the farm chores and changes were made designed to make the work easier and to save time. These changes were of four general types:

1. Rearrangement of the stables.
2. Improvement of work routines.
3. Provision of adequate and suitable equipment.
4. Convenient location of tools and supplies.

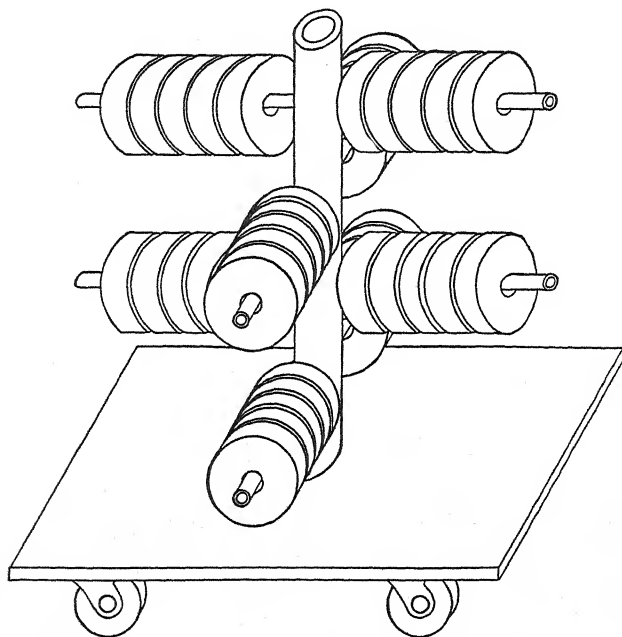


FIG. 17. Special truck-rack for holding buffing wheels. Racks are used for wheel storage between operations and also hold wheels while they are in drying oven.

As a result, the time spent on chores was reduced from 5 hours 44 minutes to 3 hours 39 minutes daily, a saving of 2 hours 5 minutes, and the travel was reduced from  $3\frac{1}{4}$  to  $1\frac{1}{4}$  miles per day, a saving of 2 miles. Two hours a day is equivalent to more than 90 eight-hour working days in a year; 2 miles daily is equivalent to 730 miles yearly.

The lines in Fig. 18 show the amount of walking required to feed silage to the cows when the silage was carried from the silo in a bushel basket. Figure 19 shows the travel required after a two-wheel cart was used for hauling the silage. The total time to throw down the



silage and feed 22 cows was reduced from 26.4 minutes to 14.8 minutes and the travel was reduced from 2070 feet to 199 feet.<sup>5</sup>

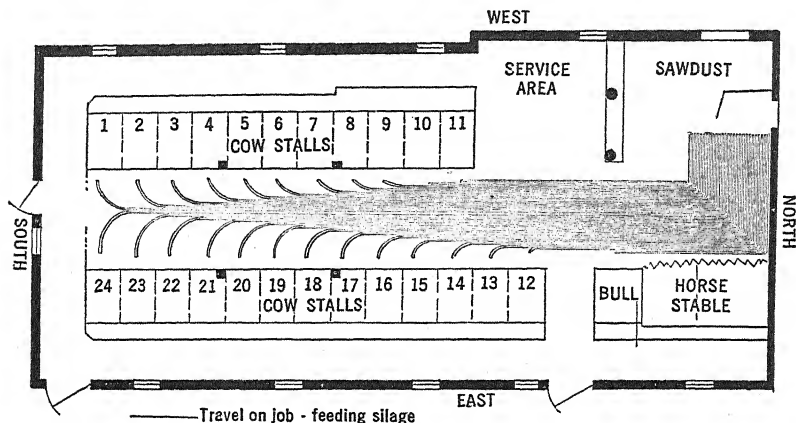


FIG. 18. Flow diagram of feeding silage to cows on small dairy farm—old method. Distance traveled 2070 feet.

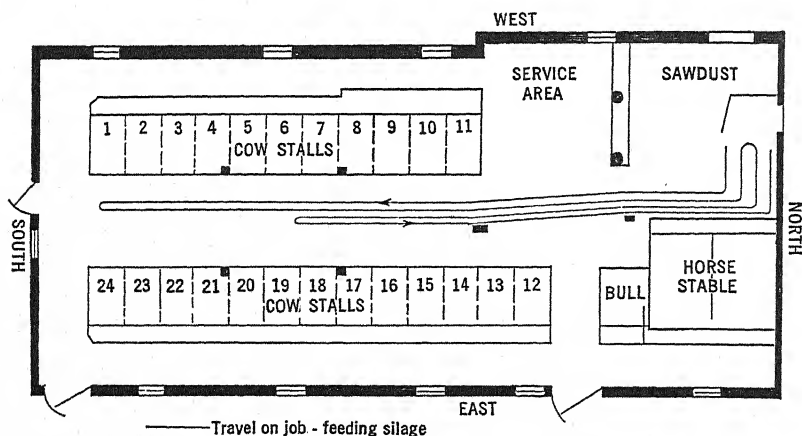


FIG. 19. Flow diagram of feeding silage to cows on small dairy farm—improved method. Distance traveled 199 feet.

**Assembly Process Charts.** A special type of process chart, sometimes called an assembly process chart, is useful for showing such situations as the following: when several parts are processed separately and are then assembled and processed together; when a product is dis-

<sup>5</sup> R. M. Carter, "Labor Saving through Job Analysis," *Bulletin* 503, p. 36, University of Vermont and State Agricultural College.



assembled and the component parts are further processed, such as the animal in the packing house; and when it is necessary to show a division in the flow of work, such as separate action on different copies of an office form.

Figure 24 shows the assembly process chart for the bolt and washer assembly described on page 194. The chart shows the bolts, lock wash-

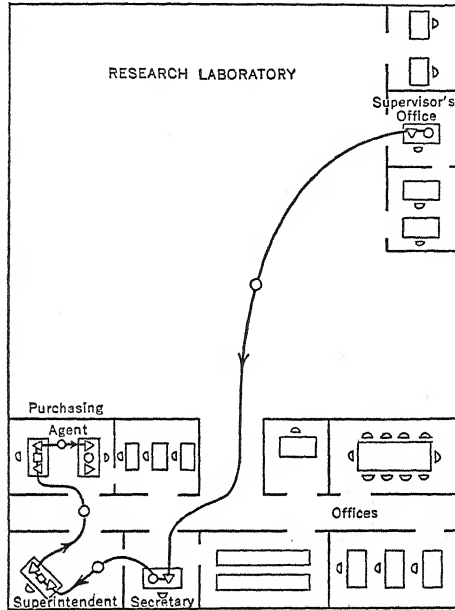


FIG. 20. Flow diagram of an office procedure—present method. Requisition is written by supervisor, typewritten by secretary, approved by superintendent, approved by purchasing agent, and a purchase order is typewritten by stenographer.

ers, and flat steel washers received in the stores department as purchased parts. They are inspected and stored there, and when needed they are drawn out and moved to the assembly bench. The material for the special rubber washers for the assembly is received in sheets. This material is inspected and stored. When needed it is drawn out, moved to the punch press where it is made into washers, and then the washers are moved to the assembly bench in Department A37. There the two steel washers and the rubber washer are assembled onto the bolt. This unit forms a subassembly, which is moved to the final assembly floor where it goes into the assembly of a steel cabinet. The entire process, from receipt of the materials until the subassembly goes to the final assembly floor, is pictured on this process chart.



## PROCESS ANALYSIS

Present Method <input checked="" type="checkbox"/>		Proposed Method <input type="checkbox"/>		PROCESS CHART	
SUBJECT CHARTED Requisition for small tools				DATE 12-10-47	
Chart begins at supervisor's desk and ends at typist's desk in purchasing department				CHART BY J. C. H.	
DEPARTMENT Research laboratory				CHART NO. R 136	
				SHEET NO. 1 OF 1	
DIST. IN FEET	TIME IN MINS.	CHART SYMBOLS	PROCESS DESCRIPTION		
		● ○ ▽ □	Requisition written by supervisor (one copy)		
		○ ○ ▽ □	On supervisor's desk (awaiting messenger)		
65		○ ○ ▽ □	By messenger to superintendent's secretary		
		○ ○ ▽ □	On secretary's desk (awaiting typing)		
		● ○ ▽ □	Requisition typed (original requisition copied)		
15		○ ○ ▽ □	By secretary to superintendent		
		○ ○ ▽ □	On superintendent's desk (awaiting approval)		
		○ ○ ▽ ■	Examined and approved by superintendent		
		○ ○ ▽ □	On superintendent's desk (awaiting messenger)		
20		○ ○ ▽ □	To purchasing department		
		○ ○ ▽ □	On purchasing agent's desk (awaiting approval)		
		○ ○ ▽ ■	Examined and approved		
		○ ○ ▽ □	On purchasing agent's desk (awaiting messenger)		
5		○ ○ ▽ □	To typist's desk		
		○ ○ ▽ □	On typist's desk (awaiting typing of purchase order)		
		● ○ ▽ □	Purchase order typed		
		○ ○ ▽ □	On typist's desk (awaiting transfer to main office)		
		○ ○ ▽ □			
		○ ○ ▽ □			
		○ ○ ▽ □			
		○ ○ ▽ □			
		○ ○ ▽ □			
		○ ○ ▽ □			
		○ ○ ▽ □			
105		3 4 8 2	Total		

B102

Fig. 21. Process chart of an office procedure—present method.



Figure 25 shows a longer and more complicated process, that of baking soda crackers. Figure 26 shows the process chart of making, painting, filling, and closing a rectangular tin can for the export shipment of instruments. Part of this process is described on pages 415 to 418.

The raw material goes into stores and then through the various can-making operations. The two parts of the can are sprayed, the product

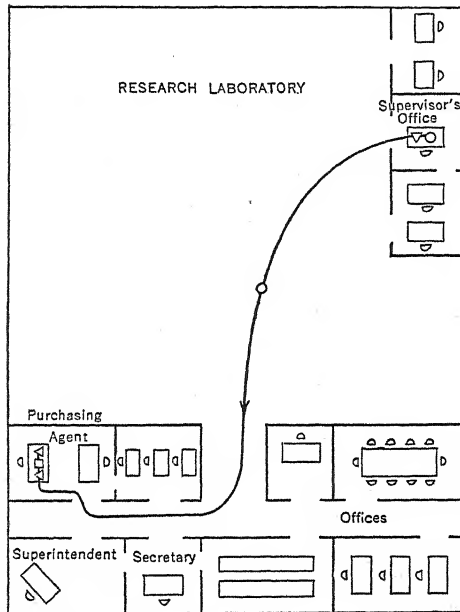


FIG. 22. Flow diagram of an office procedure—proposed method. Requisition is written in triplicate by supervisor, and approved by the purchasing agent.

inserted into the can, the can soldered shut, and the spraying completed.

A study of the process chart shows several long moves that should be eliminated. Also, from general observation of the spraying operations it is apparent that some improvement might be possible. The can cover is sprayed on the outside with the exception of a strip around the edge where it will be soldered to the bottom. In like manner the bottom of the can is sprayed on the outside with the exception of a strip around the edge for soldering it to the cover. After these spraying operations, the two parts are assembled and moved 2500 feet to a storeroom, and then 570 feet to the packing department to be filled.







The filled cans are moved 3000 feet to be soldered shut and then moved to still another building where the unpainted portion of the outside of the filled can is painted.

As a result of a careful study of this entire process the three spraying operations were eliminated entirely and one dipping operation substituted for them. Cleaning the cans before dipping them in lacquer was

## PROCESS CHART

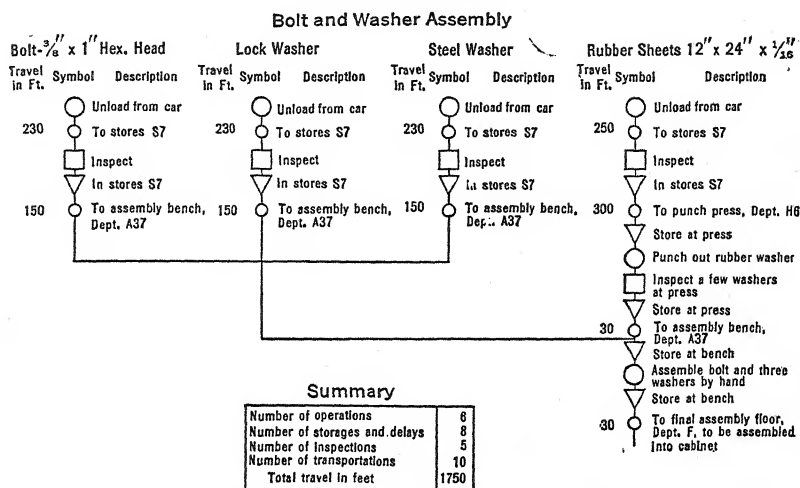


Fig. 24. Assembly process chart—bolt and washer assembly.

also found to be unnecessary—a procedure required in the spraying operations.

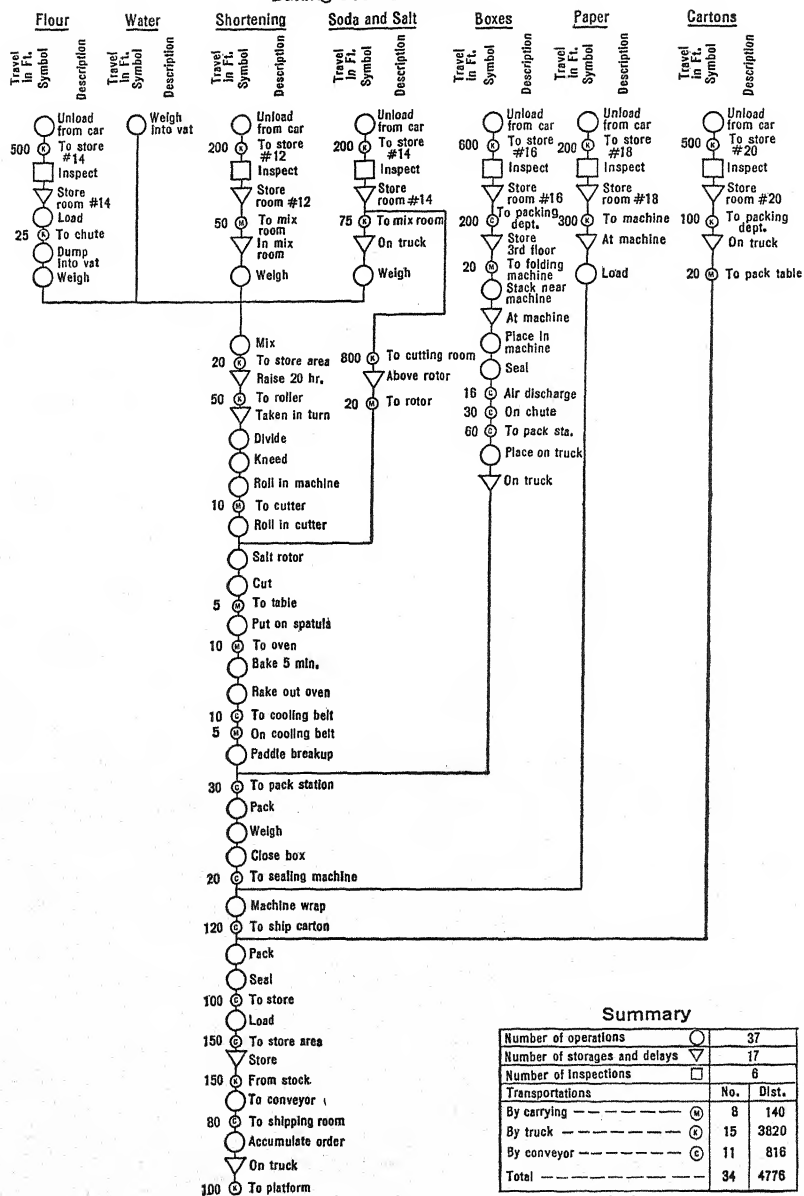
The process chart of the improved method is shown in the lower right-hand corner of Fig. 26. A summary gives the savings resulting from the improved method.

An overall investigation should be the first one made because entire operations or series of operations may be eliminated in this way. It would have been a waste of time to have made a minute study of the cleaning and of the spraying operations in the above case with the idea of improving them, only to find later that all of them could be eliminated.

No matter how complicated or intricate the manufacturing process may be, a process chart can be constructed in the same manner and serves the same purpose as those in the examples above. It is sometimes desirable to have photographs either of the work place or of a key set of motions put on the process chart at the appropriate place.



## Baking Soda Crackers



## Summary

Number of operations	○	37
Number of storages and delays	▽	17
Number of inspections	□	6
Transportations		
By carrying	○	8 140
By truck	○	15 3820
By conveyor	○	11 816
Total		34 4776

Fig. 25. Assembly process chart—baking soda crackers.







PROCESS CHART - MAGNET ARMATURE  
OLD METHOD

Travel in ft.	Symbol	Description
	1	Select Strip Stock in Raw Material Store
60	2	To Punch Press Dept.
	3	Blank
100	4	To Heat Treat Dept.
	5	Pack
	6	Anneal
	7	Unpack
150	8	To Punch Press Dept.
	9	Straighten
	10	Swage
180	11	To Elevator
	12	Up One Floor
370	13	To Straightening Dept.
	14	Straighten for Mill
	15	Straighten End Bearings
280	16	To Milling Dept.
	17	Straddle Mill
290	18	To Burring Dept.
	19	Burr Edges
370	20	To Elevator
	21	Down One Floor
180	22	To Punch Press Dept.
	23	Form Hook
180	24	To Elevator
	25	Up One Floor
370	26	To Straightening Dept.
	27	Straighten Post
	28	Straighten for Hollow Mill
430	29	To Large Drill Press Dept.
	30	Drill and Hollow Mill
80	31	To Small Drill Press Dept.
	32	Countersink and Ream
300	33	To Inspection Dept.
	34	Inspect
170	35	To Burring Dept.
	36	Burr Ends
200	37	To Milling Dept.
	38	Mill Hook
280	39	To Straightening Dept.
	40	Grit and Burr Hook
	41	Straighten to Gauge
	42	File Hook to Gauge 1
	43	File Hook to Gauge 2
	44	Burr Hook
170	45	To Inspection Dept.
	46	Inspect
210	47	To Elevator
	48	Down One Floor
140	49	To Heat Treat Dept.
	50	Pack
	51	Carburize
	52	Unpack
	53	Harden Point
140	54	To Elevator
	55	Up One Floor
370	56	To Straightening Dept.
	57	Scrape off Lead
170	58	To Inspection Dept.
	59	Inspect
110	60	To Elevator
	61	Down One Floor
170	62	To Stock Room
	63	Store

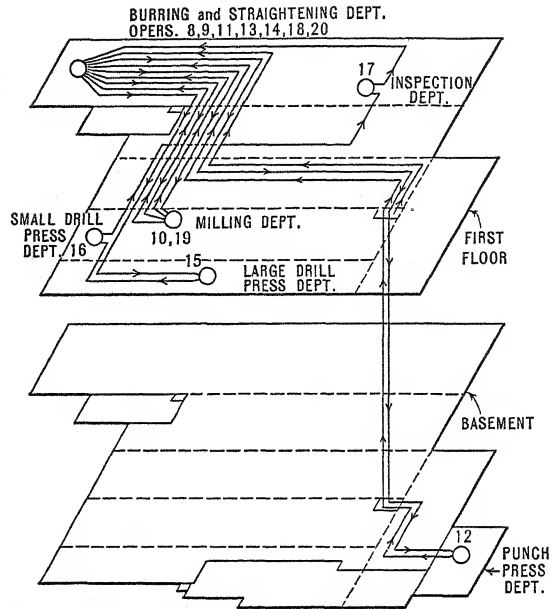


FIG. 29. Layout for making magnet armature—old method.

Occasionally time values are set opposite each operation on the process chart.

### The Process Chart as an Aid in Plant Layout.

The process chart is also a valuable aid in making a new layout or in rearranging equipment already in use. The following case will illustrate how B. C. Koch, while standards supervisor, of the International Business Machines Corporation, used the process chart for this purpose. The process is that of making a magnet armature (see Fig. 27) for a tabulator.

As Figs. 28 and 29 show, 31 operations were originally required and the part traveled 5710 feet during the course of manufacture. The process charts in Figs. 28 and 31 do not show

FIG. 28. Process chart of old method of making magnet armature.



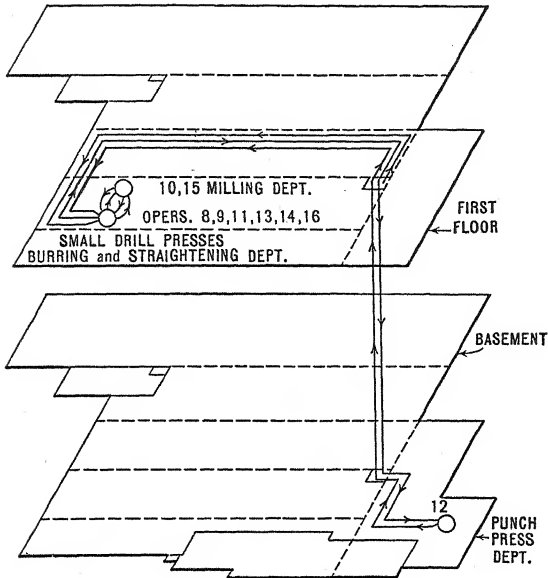


FIG. 30. Layout for making magnet armature—improved method.

PROCESS CHART - MAGNET ARMATURE  
IMPROVED METHOD

Travel in Ft.	Symbol	Description
320	⑧	To Drill Press Dept.
	⑧	Straighten for Mill
	⑨	Straighten for end Bearings
60	⑩	To Milling Dept.
	⑩	Straddle Mill
60	⑪	To Drill Press Dept.
	⑪	Burr Edges
320	⑫	To Elevator
	⑫	Down One Floor
180	⑬	To Punch Press Dept.
	⑬	Form Hook
180	⑭	To Elevator
	⑭	Up One Floor
320	⑮	To Drill Press Dept.
	⑮	Straighten Bearings
	⑮	Drill and Hollow Mill, Countersink and Burr
60	⑯	To Milling Dept.
	⑯	Mill Hook
60	⑰	To Drill Press Dept.
	⑰	Grind and burr Hook

FIG. 31. Process chart of improved method of making magnet armature.

the temporary storage symbols because it is understood that in all the manufacturing operations in this factory there is a temporary storage immediately preceding and immediately following each operation.

A study of this process chart and of the flow lines on the floor plans in Fig. 29 led to a rearrangement of equipment. A small bench containing a disk grinder and some special filing fixtures was moved from the "bench-work department" to the drill-press department. This permitted an improvement in several operations. Figures 30 and 31 show those operations (numbers 8 to 16) affected by the change.

The improved layout resulted in the following:

1. All drilling operations were performed on one drill press.
2. Two inspection operations were combined.
3. Two straightening and two burring operations were combined.
4. Four moves were eliminated.
5. The total distance traveled was reduced from 5710 feet to 3750 feet, a reduction of 34 per cent.



6. The total manufacturing time was reduced from 16.0 to 11.5 hours per hundred pieces, a reduction of 28 per cent. (See also Table III.)

**Gang Process Charts.** The gang process chart is an aid in studying the activities of a group of people working together.<sup>6</sup> This chart is a composite of individual member process charts arranged to permit thorough analysis. Those operations which are performed simultaneously by gang members are indicated side by side. The basic purpose of the chart is to analyze the activities of the group and then compose the group so as to reduce to a minimum all waiting time and delays.

### Construction

1. The same symbols are used as for ordinary "Process Charts."
2. A process chart covers the cycle or routing followed by each member of the gang. Member charts are placed side by side, with steps which are performed simultaneously shown on the same horizontal line. Figure 32 shows the form used for gang charts. The dots aid in chart construction, symbols being centered around the dots.
3. So that symbols of member charts may be placed close together, the various steps are given code numbers rather than entering descriptions beside each symbol. Numbers are entered in the center of each symbol and corresponding explanations are placed at the side of the chart. This eliminates repetition of the description when similar steps are repeated, and at the same time permits the member charts to be placed close together.
4. Attention must be paid to entering simultaneous steps side by side. It may be found that an operation performed by one member of the group continues while another is performing more than one operation. In such instances, the symbol is repeated at each step for the operation which occupies the larger number of steps. On the chart in Fig. 32 it will be noted that the transportation distance was broken down to intervals of 20 feet, as movement over this distance was accomplished while one step of another worker was started and completed. Such divisions of transportation distances are approximate, but for the purpose of analysis are sufficient.
5. The chart should cover a complete cycle for the member performing the largest number of steps. Other gang members usually repeat their cycles during the largest member cycle.
6. Elements which do not occur in every cycle may be omitted from the chart. This includes preparatory work which is done before a cycle is started, such as obtaining supplies for an entire shop. On the other hand, if an operational step occurs at periodic intervals within the cycle, such as the moving of

<sup>6</sup> The gang process chart was originated by John A. Aldridge. Description of chart and illustrations presented here are taken from Army Service Forces Manual. Also see "Gang Process Charts in Work Simplification," by John V. Valenteen, *Factory Management and Maintenance*, Vol. 104, pp. 125-127, November, 1946.











empty pallets as shown under operation 6 in Fig. 33, it should be included on the chart. If such an operation occurs every two or three cycles, enough cycles should be shown to include the operation.

7. The summary usually takes a different form from that described in the first part of this chapter. Steps per unit before and after study are used in gang summaries. This ratio is obtained by dividing the total steps on the chart by the total units handled for the cycles represented on the chart. On the chart illustrated in Fig. 32 the total steps are 120 and the total units (cases) handled are 24, four cases are loaded on a truck and 6 trucks are loaded in the cycle shown on the chart. One hundred and twenty divided by 24 equals 5 steps per unit.
8. A chart should not be constructed from observation of a single cycle. A number of cycles should be observed as the amount of waiting time may vary from cycle to cycle. The average condition should be reflected by the chart.

### Analysis

Four steps are followed in analyzing a gang process chart. First, the six questions what, why, who, where, when and how are asked of the entire process. Next, each operation and inspection is analyzed by utilizing the same six questions. Third, study the remaining transportations and storages. These three steps are the same as those used in analyzing individual process charts. The fourth step consists of applying the "How" question in a new way after refinements have been completed under steps 1, 2, and 3. This question is asked, "How should the gang be composed to reduce waiting time to the minimum?" The following will assist the analyst to "balance" the gang under step four:

1. Determine the class of operator having the largest amount of waiting time per cycle and the class having the least.
2. Adjust the gang by decreasing number of operators least busy and decreasing number of operators most busy. Generally, it is preferable to work towards a smaller rather than a larger gang.

*A Specific Case.* The activity to be considered is unloading a car of canned goods. (See Figs. 32 and 33.) In answer to the "How" question it was decided that the work could be performed better if a lift truck were used to transport the material and if pallets were loaded in the car. It was determined that one lift truck could service two cars. These questions resulted in a radical change in the entire procedure. The substitution of the lift truck eliminated all truckers and stackers.

**Arrangement of Lathes for Machining Ends of Casings.** Figure 34 shows an installation of twelve Gisholt heavy-duty turret lathes laid out to machine taper seals concentric with threads for leakproof pressure joints on standard seamless line casings. Each pair of turret lathes is placed end to end with a roller table between. The lathes machine the two ends of casings 30 to 40 feet long with a minimum of handling.



**Rearrangement of Departments in a Hotel.** The process chart has had widest use in the factory as an aid in eliminating operations, improving the layout of equipment, and in reducing the amount of handling of materials. However, because of the opportunity for large

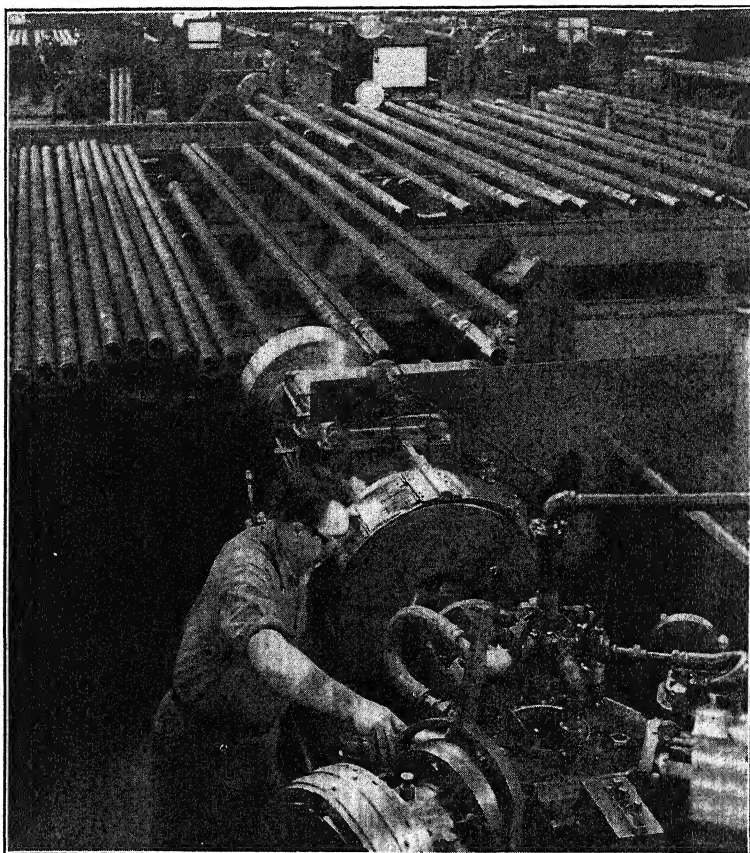


FIG. 34. Location of turret lathes on either side of table permits machining the ends of casings with a minimum of handling.

savings, offices, banks, restaurants, and hotels are using this approach in studying many of their processes.

Because of the success which Hotel Lowry has had in this field, it seems appropriate to cite some of the results of their work. H. E. Stats, under whose direction this work was carried on, states that, whereas the original objective was to study the plant layout for the purpose of improving space utilization and materials handling, they were so successful in doing this that they extended the scope of the



work to include a well-rounded small-scale application of scientific management in:

1. Plant layout and materials handling.
2. Personnel, including training and improvement on individual and group productivity.<sup>7</sup>
3. Service functions (including cost accounting, analysis of printed forms, maintenance policies, etc.).
4. Use of scientific administration in the overall organization setup.<sup>8</sup>

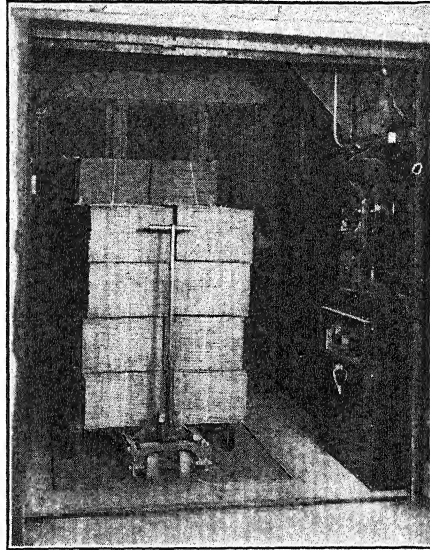


FIG. 35. One container manufacturer placed scales in the floor of elevators to eliminate unnecessary movement of folded cartons ready for shipment.

The hotel employed approximately 250 people and was able to carry on all engineering activities at a cost of less than one-half of one per cent of the total sales of the company.

The following paragraphs summarize some of the changes that were made:

1. All stores were consolidated into one unit directly responsible to a newly created centralized purchasing department. Seven executives<sup>9</sup> who had

<sup>7</sup> H. E. Stats, "Personnel Relations in Hotel Management," *Journal of Society for the Advancement of Management*, Vol. II, No. 4, p. 101.

<sup>8</sup> H. E. Stats, "Evolution of an Organization Plan," *Proceedings of the Minnesota Hotel Association*.

<sup>9</sup> Manager, Auditor, Catering Manager, Chef, Steward, Housekeeper, and Building Superintendent.



- spent part of their time buying under the old system, where each department did its own purchasing, were released from this responsibility and made available for additional supervisory duties.
2. The receiving department was combined with the central stores department, eliminating the receiving room entirely as a separate function.
  3. A complete change in the location of the linen room, resulting in the consolidation of two other departments (the work dispatching department and the service bureau), made it possible for the functions of these departments to be handled easily by the service bureau alone. Control on supplies and personnel was increased by the move.
  4. The woodworking, paint, and repair shops, originally located in three separate rooms on different floor levels, were consolidated in a works department room, formerly used as a rubbish catch-all.
  5. Re-location of the bottling department resulted in a large reduction of labor and equipment expenditures.
  6. Removal of the butcher department from the stores on the basement level to the kitchen on the main floor eliminated the last necessity for direct departmental issues of raw materials. Cut meats are now more quickly available for preparation and the butcher is now able to utilize his spare time on other kitchen work.
  7. Perhaps the most revolutionary change in layout and materials handling was the centralization of all dishwashing in one department adjoining the main kitchen. This department is fed by an overhead chain conveyor which also runs to the Coffee Shop kitchen. The conveyor is also used for transporting food orders and raw materials between the kitchens.

### Centralization of Dishwashing Department

- A. Toweling of dishes and glasses is now completely automatic. New equipment dries dishes and glasses automatically.
- B. Use of conveyor for transferring food orders allows complete shutdown of one kitchen when production falls below a certain point. Orders are transmitted by intercommunicating loud speakers and delivered by conveyor.
- C. Rhythm of moving conveyor paces other kitchen operations.<sup>10</sup>
- D. The conveyor is used for storage of dirty dishes during production peaks, eliminating production bottleneck and breakage because of congestion in dishwashing department.
- E. The conveyor is used for temporary storage of clean dishes during production valleys, eliminating unnecessary handling and stacking.
- F. Dishwashing personnel concentrated in one location simplifies supervision.

**Careful Process Analysis Is Required for Mechanized Production Lines.** When a factory is laid out for the production of a specific

<sup>10</sup> Kitchen department heads have reported an unusual psychological influence on employees in the department as a result of the presence and constant, regular motion of the overhead chain conveyor, apparently assisting the employees in maintaining a steady and smooth work pace, even though not directly connected with the conveyor.



product in quantity, the process of manufacture is studied with great care, and the machinery, equipment, and work stations are located so that the product will flow through the plant with the least amount of backtracking and lost motion. The path of travel for each part and subassembly is worked out before the equipment is installed in the plant.

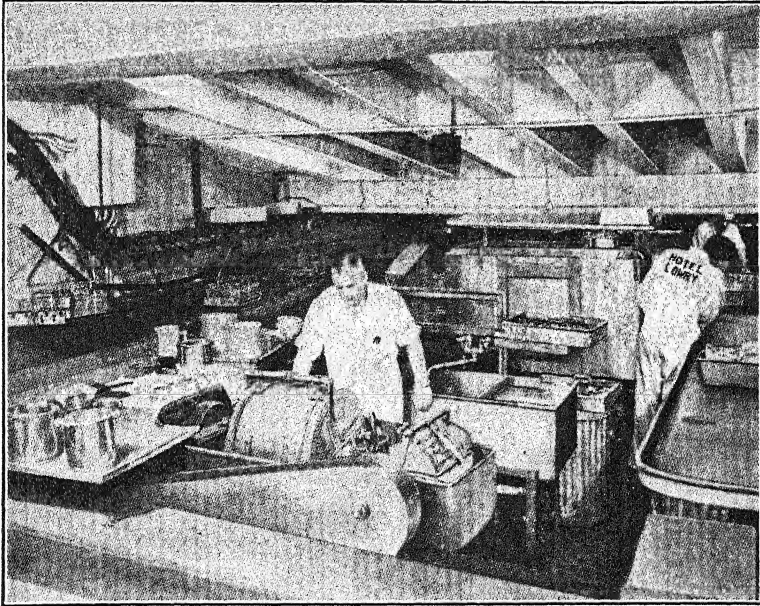


FIG. 36. Centralized dishwashing department, silver burnisher in foreground; two dishwashing machines and chain conveyor which carries dishes in background.

The layout (see Fig. 37) showing one department in the Ford plant illustrates this type of manufacture. Most factories, however, are not laid out in this manner. Rather the material moves from work station to work station intermittently by truck, and in many cases little thought has been given to the sequence of operations or to the path of travel through the plant. Because of this fact there are usually many opportunities to save time and money through an analysis of the process.

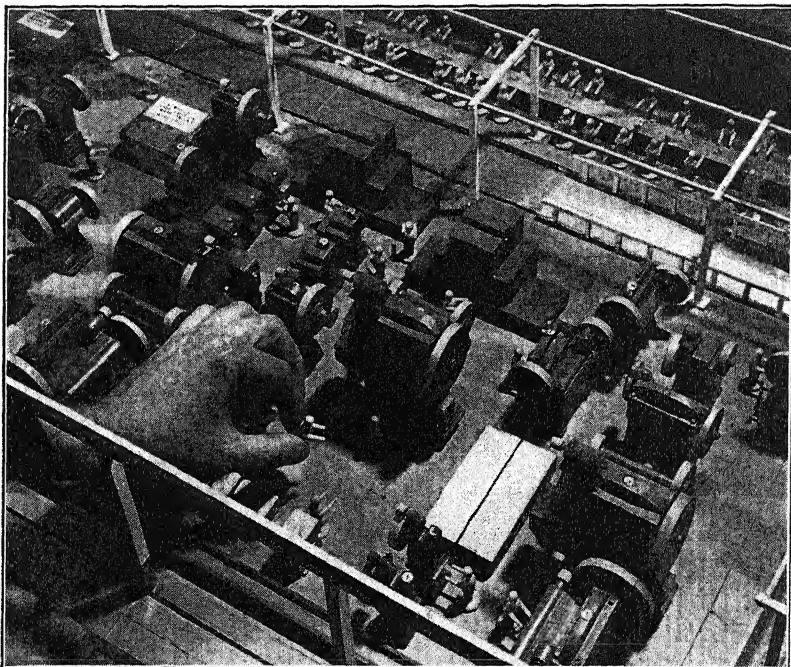
#### Steps to Be Followed in Making a Process Chart and Flow Diagram.

1. Determine the activity to be studied. Decide whether the subject to be followed is a person, part, material, or printed form.



Do not change subjects during the construction of the process chart.

2. Choose a definite starting point and ending point in order to make certain that you will cover the activity that you want to study.



*Courtesy of Ford Motor Company*

FIG. 37. Model of mechanized production line at the Ford Motor Company. Careful analysis of the process was made, including the use of three-dimensional models of machines and operators, before the actual machinery and equipment were installed.

3. The process chart should be drawn on a sheet of paper of sufficient size to allow space for (a) the heading, (b) the description, and (c) the summary. The heading should identify the process being studied. The body of the process chart should contain a column for *Travel* (distance in feet), *Symbol*, *Description*, and possibly *Time*. The four process chart symbols should be used. Every step in the process should be shown if the analysis is to be of real value. Unnecessary steps and inefficiencies in the work must first be "seen" before they can be eliminated.



4. Include at the bottom of the process chart a tabular summary showing the number of operations, number of moves of each kind and distance the part was moved, number of inspections, and number of storages and delays. After improvements have been made a combined summary should be compiled giving the above information for the old method, the proposed method, and the difference.
5. Obtain floor plans of the department or the plant showing location of machines and equipment used in making the part. If these are not available, draw floor plans to scale. It is frequently desirable to mount the floor plans on a drawing board or table, cut out templates from cardboard the size of the machines (scale  $\frac{1}{4}'' = 1 \text{ ft.}$ ), and use these when new arrangements for the equipment are suggested. Sometimes three-dimensional scale models of machines and equipment are used instead of templates. (See Fig. 37.)
6. Draw on the floor plans in pencil the path of the part through the plant, noting the direction of travel by means of arrows. The flow diagram should be made on location and not from memory at a desk. Distances should be actually measured or paced off.



## CHAPTER 6

### ACTIVITY CHARTS

#### MAN AND MACHINE CHARTS

##### ACTIVITY CHARTS

Although the process chart and the flow diagram give a picture of the various steps in the process, it is often desirable to have a breakdown of the process or of a series of operations plotted against a time scale. Such a picture is called an activity chart. Figure 39 shows an activity chart for the operation of picking up castings from a tote box, carrying them 10 feet, and placing them in a sand blast. The sketch shown in Fig. 38 was made to emphasize the fact that the operator carried the castings 10 feet and returned empty handed the same distance.

The chart suggests the obvious fact that walking could be eliminated by placing the tote box beside the sand blast. The reason this was not done originally was because the sand blast was located on a 4-inch concrete platform. However, when an inclined plank runway was built, the power lift truck was able to move the tote box of castings up to the sand blast, as shown in Fig. 40. Figure 41 shows how this eliminated the walking and enabled the operator to sandblast 75 per cent more castings per hour. Incidentally, one man can now feed this sand blast where it originally required two.

The activity chart is of special value for analyzing maintenance work, jobs involving people working in gangs, and operations where the work is unbalanced and where there is "necessary" idle time.<sup>1</sup>

##### MAN AND MACHINE CHARTS

The operator and the machine work intermittently on some types of work. That is, the machine is idle while the operator loads it and while he removes the finished work from it, and the worker is idle

<sup>1</sup> For use of activity charts in petroleum production operations, see "Job Design," by H. G. Thuesen and M. R. Lohmann, *Oil and Gas Journal*, Vol. 41, pp. 115-118, Jan. 7, 1943, and pp. 36-38, Jan. 14, 1943.



while the machine is in operation. Not only is it desirable to eliminate idle time for the worker but it is also equally important that the machine be kept operating as near capacity as possible. In many instances an idle machine costs almost as much per hour as one in operation.

The first step in eliminating unnecessary waiting time for the operator and for the machine is to record exactly when each works and what each does. Most operations consist of three main steps: (1) **GET READY**, such as putting material in the machine; (2) **DO** (doing the work), such as drilling a hole; and (3) **PUT AWAY** or clean up, such as removing the finished piece from the machine.

In Fig. 42, which shows the drilling of a hole in a steel casting with a power feed drill, the steps performed by the man are listed on the left-hand side of the figure and the operation performed by the machine is listed on the right-hand side. This is a man and machine chart in its simplest form.

Very often a clearer picture of the relationship of the operator's working time and the machine time can be obtained by showing the information graphically to scale.

**Purchasing Coffee.** The simple task of purchasing a pound of coffee is used here to illustrate the operations performed by the customer, the clerk, and the coffee grinder (machine) in a grocery store. The customer walks into the coffee department, asks the clerk for one pound of coffee, specifying the brand and grind. The clerk gets the coffee, opens the package, sets the grinder, dumps the coffee into the grinder, and starts the machine. The customer and the clerk are idle during the 21 seconds the coffee is being ground.<sup>2</sup>

After the coffee is ground the clerk places it in the package and gives it to the customer. The customer then pays the clerk, who rings up the sale, gives the customer her change, and places the money in the register. The "work" or activity of the customer, clerk, and coffee grinder is shown graphically on the man and machine chart (see Fig. 43) and in tabular form at the bottom of the chart.

**Possible Changes.** The man and machine chart in Fig. 43 shows the excessive waiting time on the part of the customer and clerk while the coffee is being ground. This at once suggests that a supply of coffee be ground somewhat in advance so that the customer would

<sup>2</sup> Time is always taken and recorded in decimal minutes or decimal hours and not in seconds. However, in describing certain motion and time study techniques, such as the man and machine chart in Fig. 43, to factory operators time may be expressed in seconds because most people are more familiar with this unit.



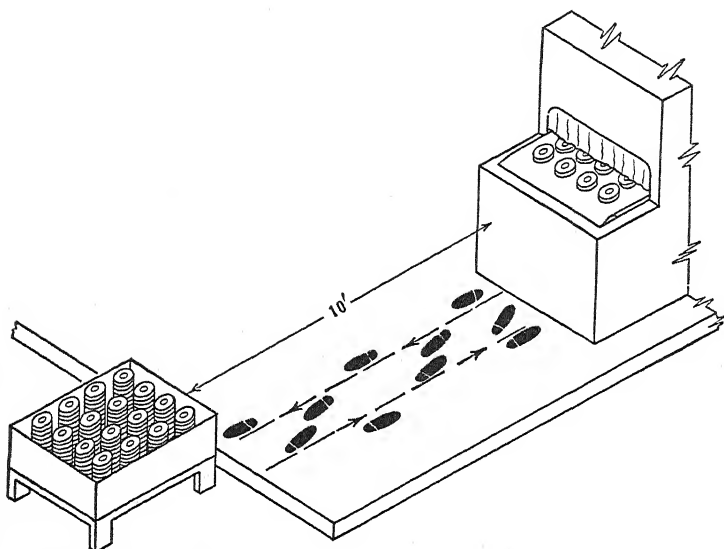


FIG. 38. Layout of work place for sandblasting castings—old method. Notice excessive walking.

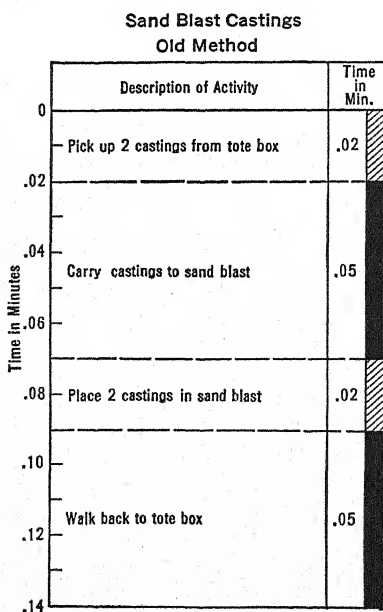


FIG. 39. Activity chart for sandblasting castings—old method.



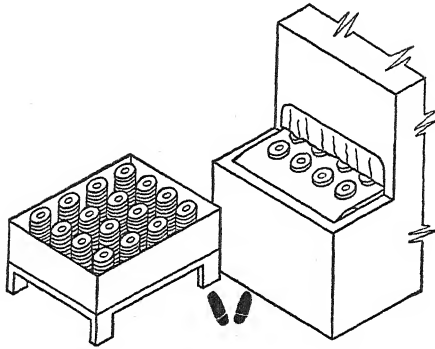


FIG. 40. Layout of work place for sandblasting castings—improved method. Unnecessary walking has been eliminated. One man now does the work of two.

Sand Blast Castings Improved Method	
Description of Activity	
Time in Minutes	
0	
Pick up 2 castings from tote box	.02
.02	
Carry through 90° to sand blast	.02
.04	
Place 2 castings in sand blast	.02
.06	
Turn through 90° to tote box	.02
.08	
Summary	
Time per trip:	
Old method-----	.14 min.
Improved method-----	<u>.08 min.</u>
Savings-----	.06 min.
$.06 \div .14 = 43$ per cent saving in time	

FIG. 41. Activity chart for sandblasting castings—improved method.



## MAN AND MACHINE CHART

## Drill Hole in Casting

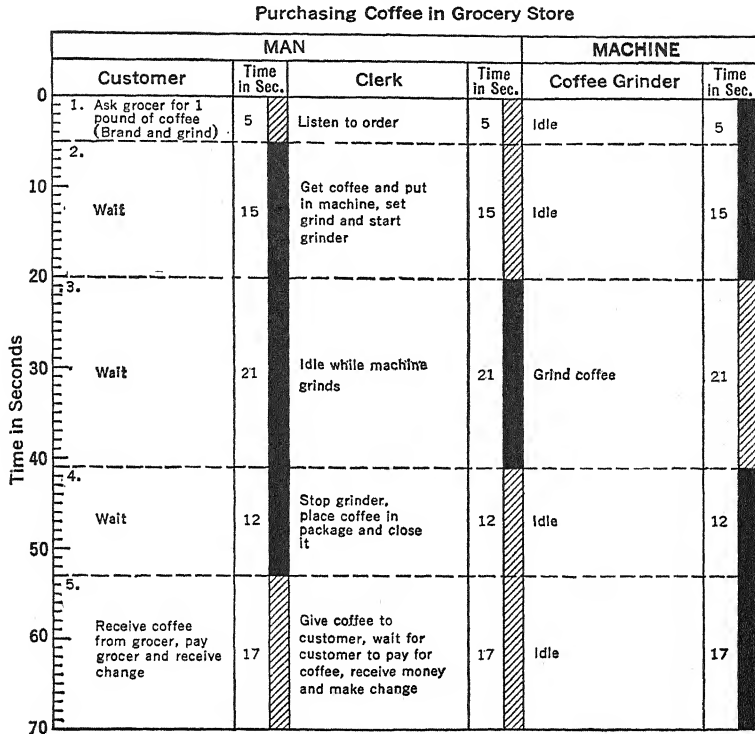
Man	Machine
1. Pick up piece, place in jig, clamp, lower drill, throw in feed. Time, $\frac{1}{2}$ minute.  (GET READY)	Idle
Idle	2. Drill $\frac{1}{2}$ -inch hole in piece. Power feed. Time, 2.5 minutes.  (DO)
3. Raise drill, remove piece, dispose, blow chips out of jig. Time, $\frac{3}{4}$ minute.  (PUT AWAY OR CLEAN UP)	Idle

## SUMMARY

	Man	Machine
Idle time	2.50 minutes	1.25 minutes
Working time	1.25	2.50
Total cycle time	3.75	3.75
Utilization in per cent	Operator utilization = $\frac{1.25}{3.75} = 33\%$	Machine utilization = $\frac{2.50}{3.75} = 67\%$

FIG. 42. Man and machine chart (simple form). It required a total of 3.75 minutes to drill the hole in the casting. During this time the operator worked  $1\frac{1}{4}$  minutes and the machine was in operation  $2\frac{1}{2}$  minutes. The operator working time was 33 per cent of the cycle, and the machine working time was 67 per cent of the cycle





### Summary

	Customer	Clerk	Coffee Grinder
Idle time	48 sec.	21 sec.	49 sec.
Working time	22	49	21
Total cycle time	70	70	70
Utilization in per cent	Customer utilization = $\frac{22}{70} = 31\%$	Clerk utilization = $\frac{49}{70} = 70\%$	Machine utilization = $\frac{21}{70} = 30\%$

FIG. 43. Man and machine chart showing activities involved in purchasing coffee in grocery store. The customer, the clerk, and the coffee grinder (machine) are involved in this operation. It required 1 minute and 10 seconds for the customer to purchase a pound of coffee in this particular store. During this time the customer spent 22 seconds, or 31 per cent of the time, giving the clerk her order, receiving the ground coffee, and paying the clerk for it. She was idle during the remaining 69 per cent of the time. The clerk worked 49 seconds, or 70 per cent of the time, and was idle 21 seconds, or 30 per cent of the time. The coffee grinder was in operation 21 seconds, or 30 per cent of the time, and was idle 70 per cent of the time.



not need to wait for her coffee to be ground. If this were done, the clerk could serve more than twice as many customers per hour, and the customer would spend less than half as much time at the coffee counter.

If the store were a large one employing a number of clerks and using a number of coffee grinders, the man and machine chart would indicate that the activities of the clerk be divided into two parts, one clerk sell-

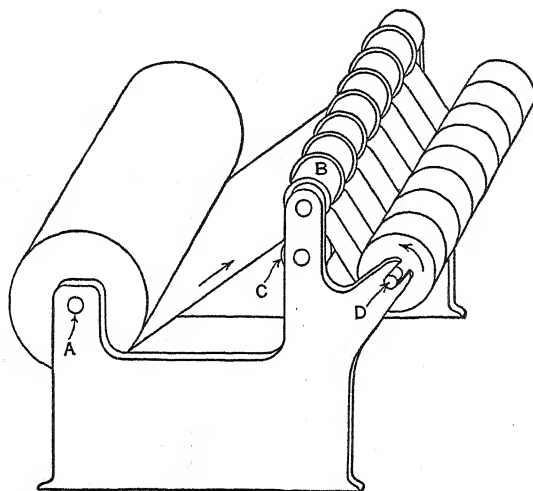


FIG. 44. Slitting machine. Coated fabric is drawn under slitting knives *B* onto the "wind up" shaft at *D*.

ing the coffee and another clerk grinding the coffee. Thus, in this hypothetical case, the coffee grinders would be kept in almost constant use, which would mean that fewer grinders would be needed. The clerks could work to better advantage inasmuch as there would be less idle time and the customer would receive faster service. This would also tend to relieve congestion in the store during rush hours. Moreover, this would mean that the store could handle more customers with a given floor area and with a given amount of equipment. However, it would be necessary to seal and date the bags containing the ground coffee so that the customer would be assured of receiving freshly ground coffee.

**Slitting Coated Fabric.** Special fabric is coated with adhesive on continuous coating machines, and the finished material is taken off the drying racks in rolls approximately 3 feet wide and 2 feet in di-



ameter. These rolls go to storage and later are removed and slit into narrower rolls to customers' orders.

The material is slit on machines similar to the one shown in Fig. 44. The roll is placed on the shaft *A* at the back of the machine. The material is passed under rotating cutters *B* which press against a rotating cylinder *C*, thus slitting the material into the desired width. The material is then rolled onto cardboard cores which are held in place on a shaft at *D*. After the desired length of fabric has been spooled the machine is stopped and the cloth is cut parallel to shaft *D*. The operator with the assistance of a helper then places wrapping paper around the spooled material, attaches a label to each roll, and marks the grade, roll length, and other information on the label. The rolls are then removed from shaft *D* and placed on a skid. During this time the slitting machine is idle.

**Improved Method.** The following change was made in the method, which increased the capacity of the slitting machines 44 per cent. A shaft was mounted on a pedestal as shown in Fig. 45. Then after the desired length of coated fabric had been slit, spooled, and cut off, the rolls were slid from shaft *D* of the slitting machine onto shaft *A* of the pedestal, as shown in Fig. 45. This is a short and simple operation. The helper then wraps, labels, and marks the rolls while the machine operator immediately starts the slitting machine, thus eliminating much of the idle machine time. Because of the design of the machine it is necessary for the operator to manipulate the slitting machine controls while the fabric is being slit. The man and machine charts, Figs. 46 and 47, show the idle time and the working time before and after the new method was developed.

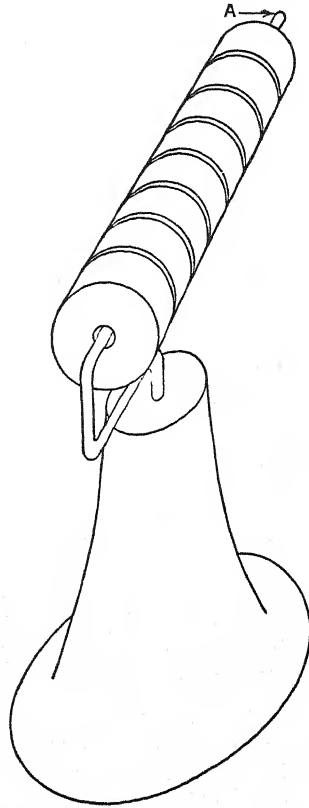


FIG. 45. Special pedestal. The rolls of fabric are transferred onto arm *A* to be wrapped and labeled.



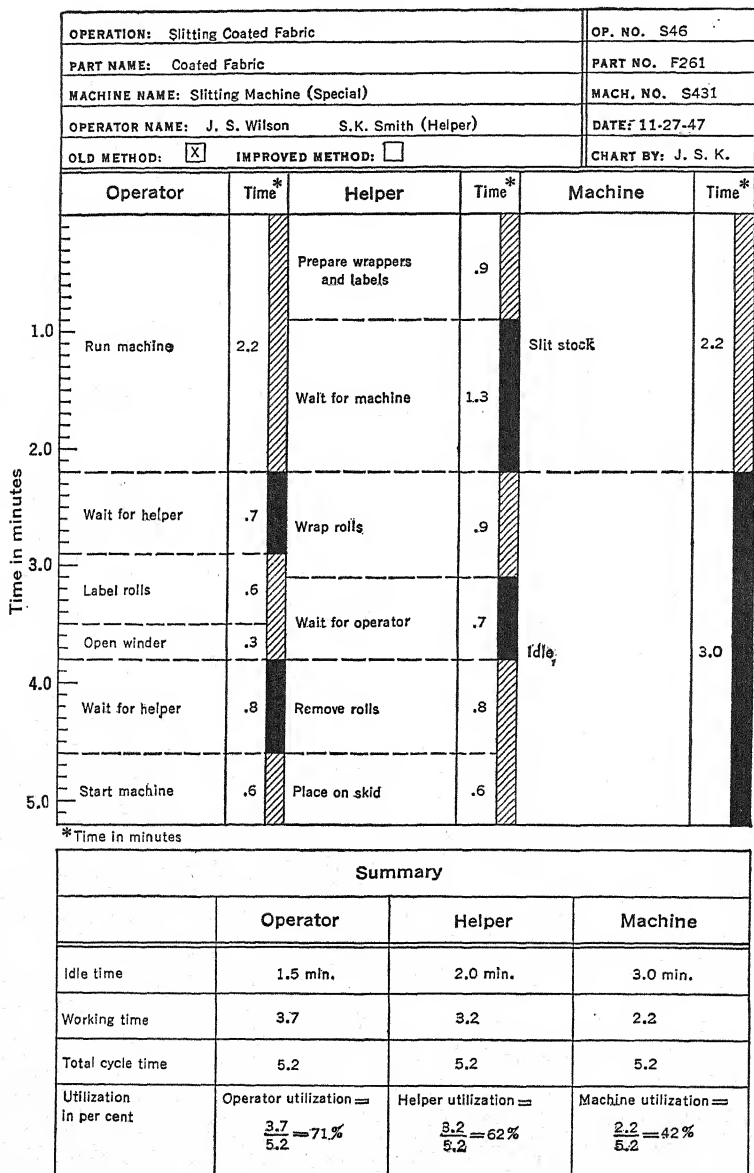
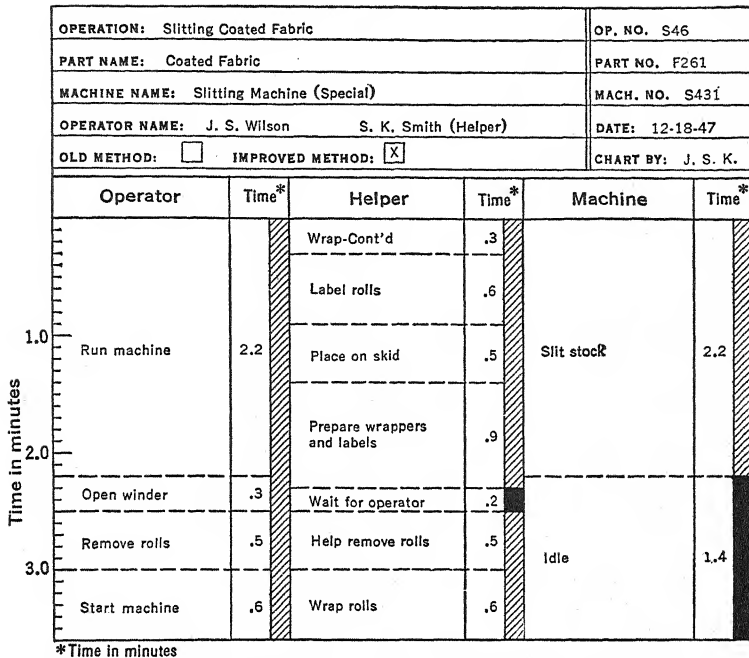


FIG. 46. Man and machine chart for slitting coated fabric—old method. Total cycle time 5.2 minutes. Total number of cuts per hour = 11.5.





Summary			
	Operator	Helper	Machine
Idle time	0.0 min.	0.2 min.	1.4 min.
Working time	3.6	3.4	2.2
Total cycle time	3.6	3.6	3.6
Utilization in per cent	Operator utilization = $\frac{3.6}{3.6} = 100\%$	Helper utilization = $\frac{3.4}{3.6} = 95\%$	Machine utilization = $\frac{2.2}{3.6} = 61\%$

FIG. 47. Man and machine chart for slitting coated fabric—improved method.  
Total cycle time 3.6 minutes. Total number of cuts per hour = 16.6.



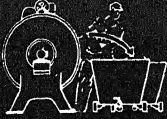
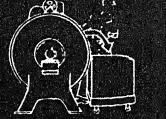

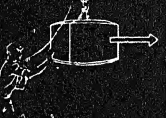


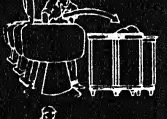


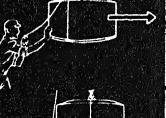




MAN-MINUTES TO PRODUCE 320 LB. BULK WORK	
WITH <b>4-30" EXTRACTORS</b> (80 LB. CAPACITY EACH)	WITH <b>1-50" EXTRACTOR</b> (320 LB. CAPACITY)
 <p>LOAD TRUCKS FROM WASHER <b>3 <math>\frac{3}{4}</math> MAN-MINUTES</b></p>	 <p>LOAD CONTAINERS FROM WASHER <b>3 <math>\frac{3}{4}</math> MAN-MINUTES</b></p>
 <p>PUSH TRUCKS TO EXTRACTORS <b>1 <math>\frac{1}{2}</math> MAN-MINUTES</b></p>	 <p>CONVEY CONTAINERS TO EXTRACTOR <b>3 MAN-MINUTES</b></p>
 <p>LOAD EXTRACTORS AND BALANCE LOADS <b>8 MAN-MINUTES</b></p>	 <p>BALANCE LOAD-PLACE CONTAINERS IN EXTRACTOR <b>1 MAN-MINUTE</b></p>
 <p>UNLOAD EXTRACTORS INTO TRUCKS <b>10 <math>\frac{3}{4}</math> MAN-MINUTES</b></p>	 <p>HOIST CONTAINERS FROM EXTRACTOR <b>1 MAN-MINUTE</b></p>
 <p>PUSH TRUCKS TO SHAKEOUT TABLE <b>1 <math>\frac{1}{4}</math> MAN-MINUTES</b></p>	 <p>CONVEY CONTAINERS TO SHAKEOUT TABLE <b>3 MAN-MINUTES</b></p>
 <p>UNLOAD TRUCKS ONTO SHAKEOUT TABLE <b>2 <math>\frac{1}{2}</math> MAN-MINUTES</b></p>	 <p>DUMP LOAD ONTO SHAKEOUT TABLE <b>1 MAN-MINUTE</b></p>
 <p>RETURN TRUCKS TO EXTRACTORS &amp; WASHERS <b>1 <math>\frac{3}{4}</math> MAN-MINUTES</b></p>	 <p>RETURN CONTAINERS TO WASHERS <b>3 MAN-MINUTES</b></p>
<p>TOTAL TIME OLD METHOD <b>29 <math>\frac{1}{2}</math> MAN-MINUTES</b></p>	<p>TOTAL TIME IMPROVED METHOD <b>8 MAN-MINUTES</b></p>
<p>TIME SAVED EACH LOAD CYCLE <b>21 <math>\frac{1}{2}</math> MAN-MINUTES</b></p>	

FIG. 48. Chart used by a laundry machinery manufacturer to show how his extractor has been designed to eliminate hand operations and save time.



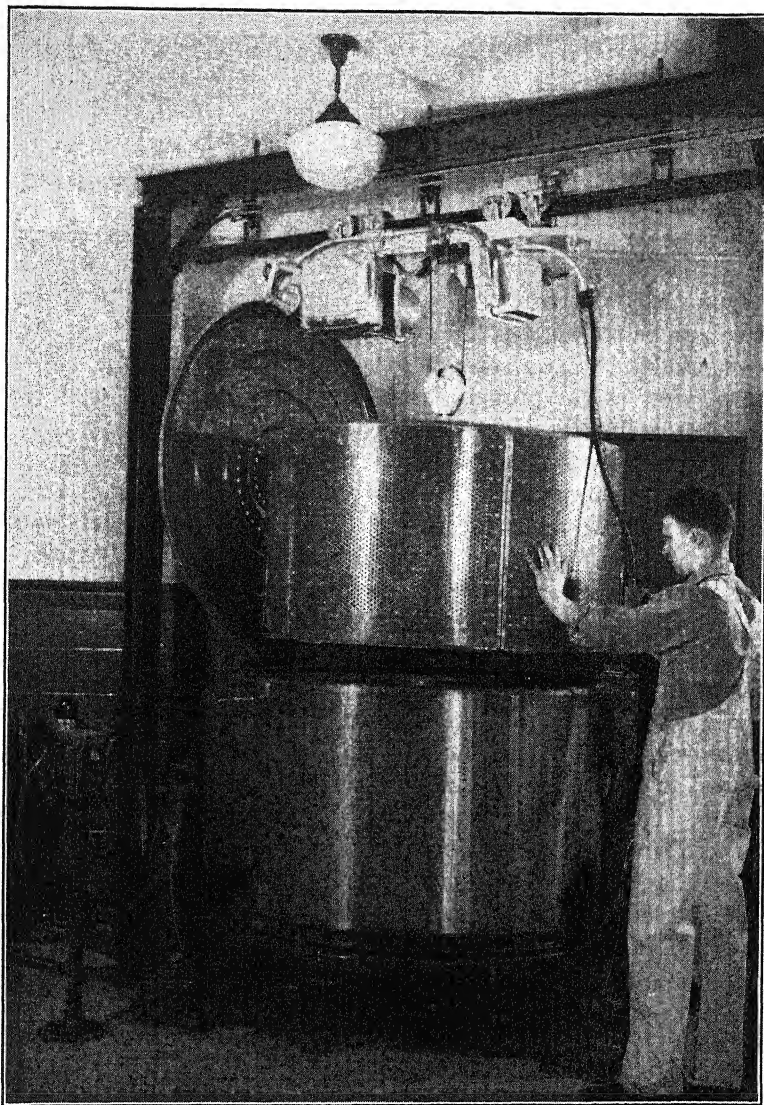


FIG. 49. Extractor used in commercial laundry to remove water from clothes by centrifugal force. The removable extractor container is made in halves, each of which is fitted with casters and a hinged bottom.



*Results.* The total cycle time was 5.2 minutes, using the old method, or 11.5 cuts were made per hour, whereas the new method reduced the cycle time to 3.6 minutes, which increased the output to 16.6 cuts per hour. This increase of 5.1 cuts per hour represents an increase of 44 per cent. As the man and machine charts show, the machine utilization was increased from 42 to 61 per cent. This was especially important in this case as these slitting machines were operating 24 hours per day 7 days per week and were still unable to supply the demand for the product.

**Design of Machines and Equipment.** Manufacturers of machines and equipment are confronted with the problem of designing machines that will do better work at a lower cost. In approaching this problem they should study the process and the individual operations from the point of view of the person who is doing the work and design the machine or equipment to save his time and energy.

The fact that new equipment saves time by eliminating some operations is often used in advertising the equipment. Figure 48 is a reproduction of part of an advertisement used by a commercial laundry machinery manufacturer to show that an extractor of improved design eliminates several hand operations and does, in 8 minutes, work that formerly took 29½ minutes. A more complete description of this work is given here.

**Extracting Water from Clothes in a Commercial Laundry—Ordinary Method.** After clothes are washed in a commercial laundry, they are removed from the washing machine by hand, placed in a truck, moved to an extractor, and unloaded by hand from the truck into the extractor. The extractor lid is then closed, and the extractor is run at high speed 10 to 15 minutes, during which time the water is thrown out of the clothes by centrifugal force.

The extractor is then stopped, the lid opened, and the clothes removed from the extractor by hand and placed in a truck. The truck is then moved to a "shake-out" table, and the clothes are removed from the truck by hand and placed on the table.

**Extractor with Removable Containers.** An extractor (see Fig. 49) is now being manufactured with a removable container or spinner basket made in two parts or halves. Each of the two parts of the container is fitted with casters, and the bottom is hinged on one side and opens downward.

With this new extractor the operation of extracting water from clothes is as follows. The halves of the container are moved to the washing machine, and the clothes are removed from the washing



machine by hand and placed in them. The container halves are then shoved together to form a cylinder (see Fig. 49) and, by means of a power hoist mounted on a monorail, the container is lifted up and moved over the extractor, balanced, and lowered in place. The extractor is run for 15 minutes. After the water is removed from the clothes, the extractor is stopped, the lid opened, and the container is lifted out of the extractor with the hoist, moved over the "shake-out" table, the hinged bottom of each half of the container opened downward, and the clothes allowed to drop on to the "shake-out" table by gravity. The bottom of each container is then closed, and the extractor is returned to the washing machine for another load of clothes.



## CHAPTER 7

### OPERATION ANALYSIS

The overall study of the process should result in a reduction in the amount of travel of the operator, materials, and tools, and should bring about orderly and systematic procedures. The man and machine chart often suggests ways of eliminating idle machine time and promotes a better balancing of the work of the operator and the machine.

After such studies have been completed it is time to investigate specific operations in order to improve them. The purpose of motion study is to analyze the motions used by the worker in performing an operation in order to find the most economical way of doing it. A systematic attempt is made to eliminate all unnecessary motions and to arrange the remaining necessary motions in the best sequence. It is when we come to the analysis of specific operations that motion study principles and techniques become most useful. Motion study consists of both analysis and synthesis.

The extent to which motion study, as well as the other phases of motion and time study, should be carried will depend largely upon the anticipated savings in cost. As Table I on page 18 shows, motion study may vary in extent from a cursory analysis followed by a general application of motion-economy principles to a detailed study of individual motions of each hand followed by a careful and extensive application of motion-economy principles. The most elaborate analysis, of course, is possible only by means of full micromotion study, which will be explained in the chapters to follow.

**Operation Charts.** For those who are trained in the micromotion study technique, that is, those who are able to visualize work in terms of elemental motions of the hands, the operation chart, or the left- and right-hand chart, is a very simple and effective aid for analyzing an operation. No timing device is needed, and on most kinds of work the analyst is able to construct such a chart from observations of the operator at work. The principal purpose of such a chart is to assist in finding a better way of performing the task, although this chart also has definite value in training operators.



Two symbols are commonly used in making operation charts. The small circle indicates a transportation, such as moving the hand to

## OPERATION CHART

Signing Letter

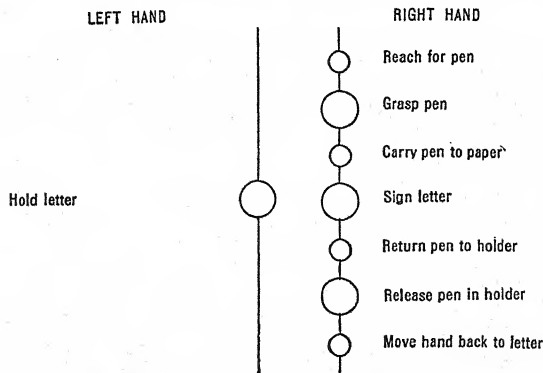
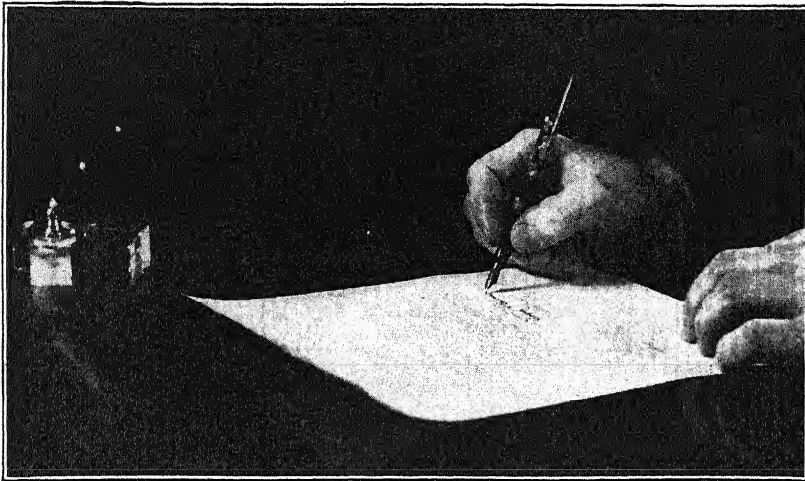


Fig. 50. Operation chart showing the movements of the two hands in signing a letter.

grasp an article, and the large circle denotes such actions as grasping, positioning, using, or releasing the article. Thus in signing a letter with a fountain pen the left hand holds the paper while the right hand performs the various movements indicated in Fig. 50.



The first step in making an operation chart or a left- and right-hand chart is to draw a sketch of the work place, indicating the contents of

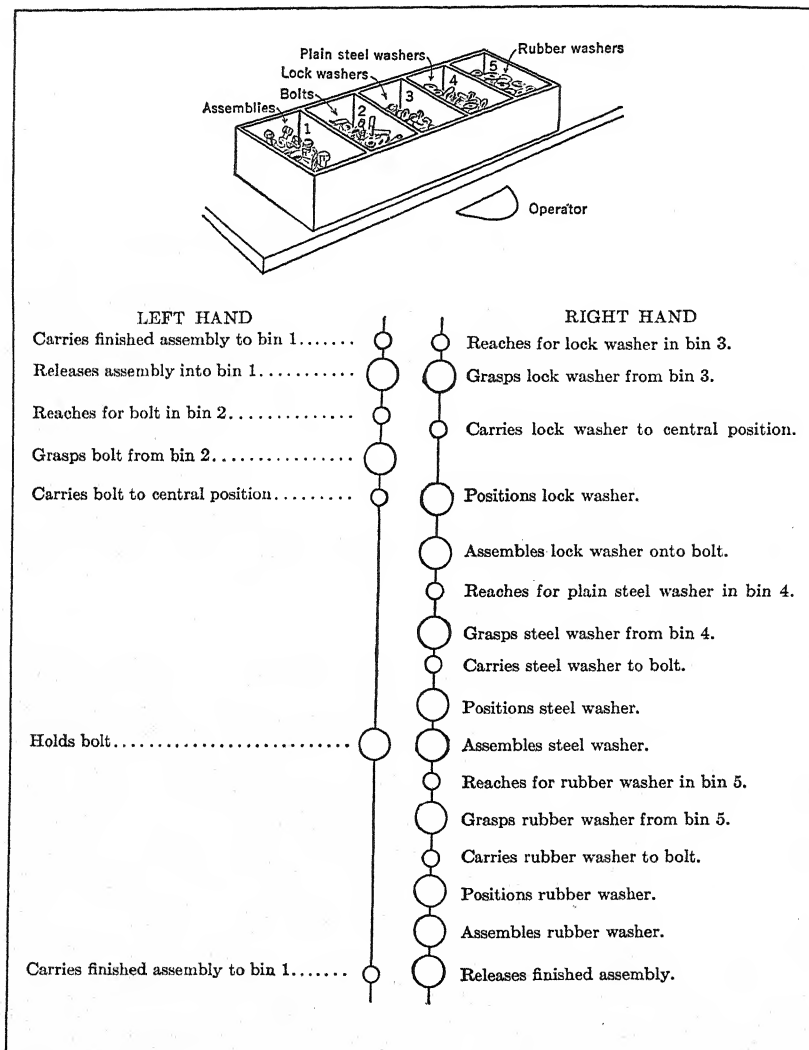
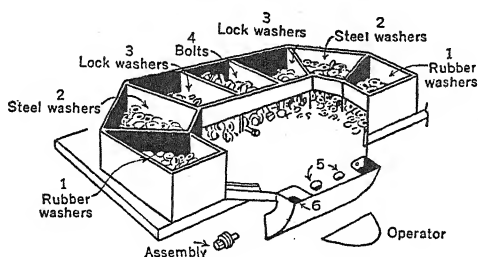


Fig. 51. Operation chart of bolt and washer assembly—old method.

the bins and the location of tools and materials. Then watch the operator and make a mental note of his motions, observing one hand at a time. Record the motions or elements for the left hand on the left-





LEFT HAND		RIGHT HAND
Reaches for rubber washer in bin 1.....	○	Reaches for rubber washer in bin 1.
Grasps rubber washer from bin 1.....	○	Grasps rubber washer from bin 1.
Slides rubber washer to countersunk hole	○	Slides rubber washer to countersunk hole.
Positions rubber washer in countersunk hole 5.....	○	Positions rubber washer in countersunk hole 5.
Reaches for plain steel washer in bin 2..	○	Reaches for plain steel washer in bin 2.
Grasps steel washer from bin 2.....	○	Grasps steel washer from bin 2.
Slides steel washer to countersunk hole..	○	Slides steel washer to countersunk hole.
Positions steel washer in countersunk hole 5.....	○	Positions steel washer in countersunk hole 5.
Reaches for lock washer in bin 3.....	○	Reaches for lock washer in bin 3.
Grasps lock washer from bin 3.....	○	Grasps lock washer from bin 3.
Slides lock washer to countersunk hole..	○	Slides lock washer to countersunk hole.
Positions lock washer in countersunk hole 5.....	○	Positions lock washer in countersunk hole 5.
Reaches for bolt in bin 4.....	○	Reaches for bolt in bin 4.
Grasps bolt from bin 4.....	○	Grasps bolt from bin 4.
Carries bolt to washers at 5.....	○	Carries bolt to washers at 5.
Positions bolt preparatory to inserting it into washers at 5.....	○	Positions bolt preparatory to inserting it into washers at 5.
Assembles bolt and washers.....	○	Assembles bolt and washers.
Lifts bolt and washers, carries to left and releases into top of chute 6.....	○	Lifts bolt and washers, carries to RIGHT and releases into top of chute 6.

FIG. 52. Operation chart of bolt and washer assembly—improved method.



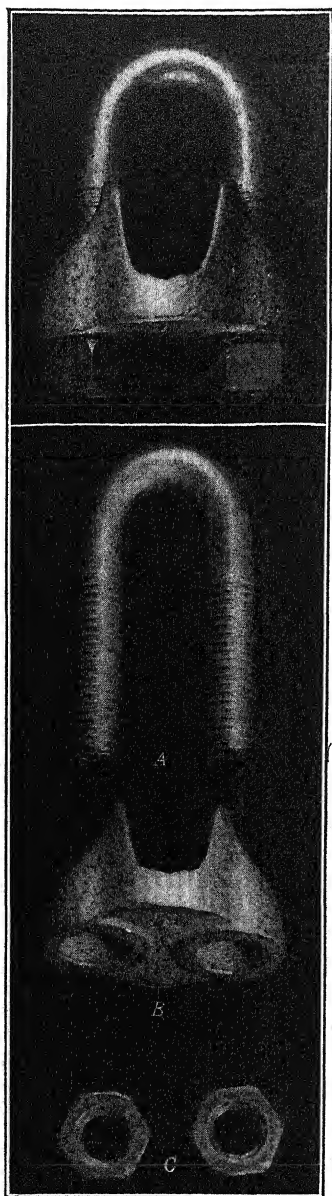


FIG. 53. Rope clip assembly: A, U bolt; B, casting; C, nuts.

hand side of a sheet of paper and then in a similar manner record the motions for the right hand on the right-hand side of the sheet. As it is seldom possible to get the motions of the two hands in proper relationship on the first draft, it is usually necessary to redraw the chart.

**Bolt and Washer Assembly.** A left- and right-hand chart of the operation of assembling a lock washer, a steel washer, and a rubber washer onto a bolt is shown in Fig. 51. This operation is described fully on page 194. A glance at the chart shows that the left hand is holding the bolt while the right hand is doing useful work, that is, assembling the washers. It is obvious that the motions of the two hands are unbalanced. The chart in Fig. 52 shows how the operation would appear if an assembly fixture were used and if the two hands worked together simultaneously.

When one has a detailed breakdown of the operation before him he is in a much better position to question each element of the job and work out an easier and better method.

**Assembling Rope Clips.** The rope clip shown in Fig. 53 consists of three different parts: A, the U bolt; B, the casting; C, the hexagonal nuts. The rope clips were originally assembled in the following manner: The operator grasped a U bolt from bin 1 (see Fig. 54) with her left hand and carried it up in front of her. Then she grasped a casting from bin 3 with her right hand and assembled it onto the bolt; and in a similar manner she grasped (from bin 2) and assembled in succession the two nuts onto the threaded ends of the bolt. She then disposed of the assembly with her right hand



into bin 4 at her right. The operation chart for this operation is shown in Fig. 54.

**Check Sheet for Operation Analysis.** One approach to the problem of finding a better way of doing the work is to subject the operation

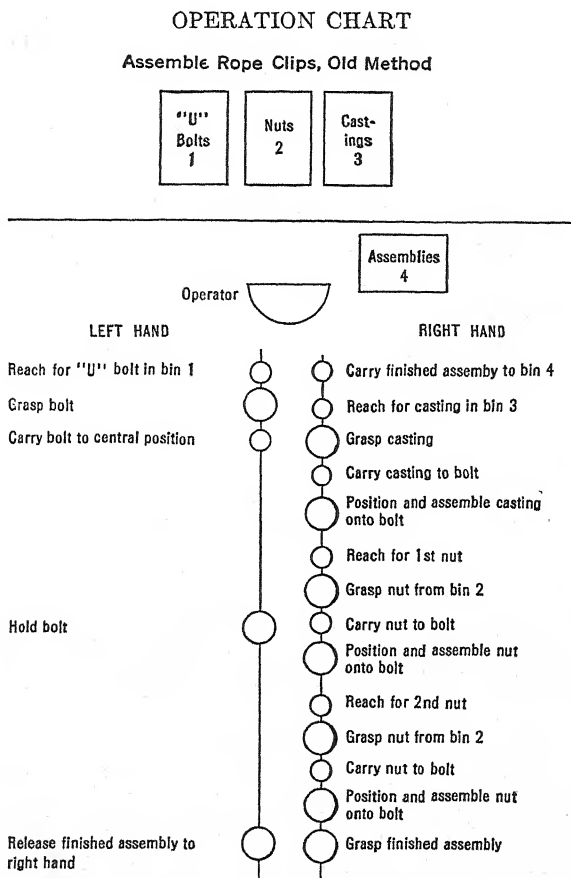


FIG. 54. Operation chart of assembling rope clips—old method.

to specific and detailed questions. If the several persons interested in the job consider these questions together, a more satisfactory solution is likely to result. In addition to studying the motions used in performing an operation, it is also desirable to give consideration to materials, tools, jigs, fixtures, handling equipment, working conditions, and other factors affecting the job. Finding the best way is not always easy, and considerable imagination, ingenuity, and inventive ability are required. Therefore, the cooperation of such persons as the fore-



man, tool-designer, and the operator are often of decided value to the analyst.

After recording all that is known about the job, the various phases of the operation should be considered, such as:

I. *Materials:*

1. Can cheaper material be substituted?
2. Is the material uniform and in proper condition when brought to the operator?
3. Is the material of proper size, weight, and finish for most economical use?
4. Is the material utilized to the fullest extent?
5. Can some use be found for scrap and rejected parts?
6. Can the number of storages of material and of parts in process be reduced?

II. *Materials Handling:*

1. Can the number of times the material is handled be reduced?
2. Can the distance moved be shortened?
3. Is the material received, moved, and stored in suitable containers? Are the containers kept clean?
4. Are there delays in the delivery of material to the operator?
5. Can the operator be relieved of handling materials by the use of conveyors?
6. Can backtracking be reduced or eliminated?
7. Will a rearrangement of the layout or combining of operations make it unnecessary to move the material?

III. *Tools, Jigs, and Fixtures:*

1. Are the tools the best kind for this work?
2. Are the tools in good condition?
3. If metal-cutting tools, are the cutting angles of the tools correct, and are they ground in a centralized tool-grinding department?
4. Can tools or fixtures be changed so that less skill is required to perform the operation?
5. Are both hands occupied by productive work in using the tools or fixtures?
6. Can "slide feeds," "ejectors," "holding devices," etc., be used?
7. Can an "engineering change" be made to simplify the design?

IV. *Machine:*

A. Setup:

1. Should the operator set up his own machine?
2. Can the number of setups be reduced by proper lot sizes?



3. Are drawings, tools, and gauges obtained without delay?
4. Are there delays in making inspection of first pieces produced?

*B. Operation:*

1. Can the operation be eliminated?
2. Can the work be done in multiple?
3. Can the machine speed or feed be increased?
4. Can an automatic feed be used?
5. Can the operation be divided into two or more short operations?
6. Can two or more operations be combined into one? Consider the effect of combinations on the training period.
7. Can the sequence of the operation be changed?
8. Can the amount of scrap and spoiled work be reduced?
9. Can the part be pre-positioned for the next operation?
10. Can interruptions be reduced or eliminated?
11. Can an inspection be combined with an operation?
12. Is the machine in good condition?

*V. Operator:*

1. Is the operator qualified mentally and physically to perform this operation?
2. Can unnecessary fatigue be eliminated by a change in tools, fixtures, layout, or working conditions?
3. Is the base wage correct for this kind of work?
4. Is supervision satisfactory?
5. Can the operator's performance be improved by further instruction?

*VI. Working Conditions:*

1. Are the light, heat, and ventilation satisfactory on the job?
2. Are washrooms, lockers, restrooms, and dressing facilities adequate?
3. Are there any unnecessary hazards involved in the operation?
4. Is provision made for the operator to work in either a sitting or a standing position?
5. Are the length of the working day and the rest periods set for maximum economy?
6. Is good housekeeping maintained throughout the plant?

The above list of questions, although by no means complete, shows some of the elements that enter into a thorough consideration of the problem of finding the best way of doing work. This list is



typical of a check sheet that can be prepared for use in a specific plant.

Another approach to the problem is to divide the job into the three phases: (1) get ready; (2) do the work (or use); and (3) put away or clean up, as has already been mentioned. The second phase is the primary object of the work, and the first and the third phases are auxiliary to it. Often the get ready and the clean up can be shortened and simplified without impairing the do or use phase of the operation.

**Spray Inside and Outside of Metal Box Covers and Bottoms.** This illustration shows the steps that were taken to improve the method of

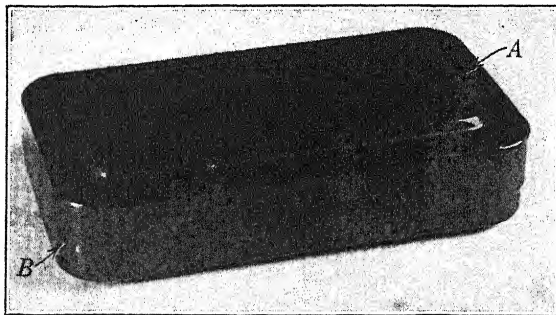


FIG. 55. Metal box: A, box cover; B, box bottom.

spray painting black enamel on the two parts of a small metal box. Of the questions listed on pages 80 and 81, the one that seemed to give the greatest promise in this case was IV-B-6—"Can two or more operations be combined into one?"—referring to the possibility of spraying the inside and the outside of the container in a single operation.

When a systematic attempt is made to find a better method it is seldom that the first one tried proves to be the best one. Finding the most economical method for doing a given task is usually a process of development and invention. The following case illustrates this in an excellent manner.

The boxes (see Fig. 55), made in slightly different sizes and shapes, are used for such products as surgical instruments and sewing machine attachments. The container is composed of a cover and a bottom which fit together to form a box. The cover is shown in Figs. 56 and 57. The containers are manufactured in lots of 5000 to 10,000.

**Original Method of Spraying Boxes.** The operator, standing in front of the spray booth, procured an unsprayed box cover or bottom with the right hand from a tote box at her right and placed it on the metal fixture A shown in Fig. 56, which she held in her left hand. She



then grasped the spray gun in her right hand and, holding the box cover inside the spray booth, she sprayed the inside surface and disposed of it on a screen tray. When the screen tray was filled (35 covers or bottoms) it was placed on an oven rack, and an empty screen was positioned at the left of the spray booth.

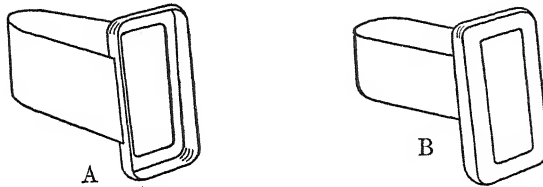


FIG. 56. Clamps for holding box covers and bottoms for spraying by the original method. *A*. For spraying inside; *B*. For spraying outside.

When an oven rack was full the oven man moved it into the baking oven on the other side of the room where it was baked for one and one-half hours. The rack was then removed, cooled, and the outside of the box covers were sprayed, using fixture *B* shown in Fig. 56. The sequence of motions used in spraying the outside was similar to

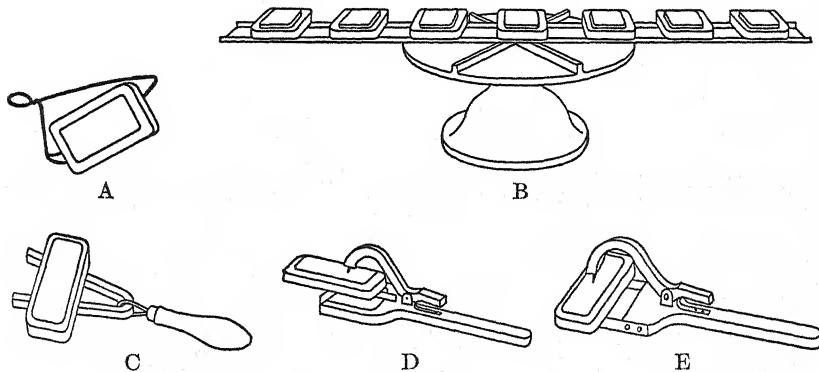


FIG. 57. Devices for use in spray-painting box covers and bottoms by "improved" methods. *A*. Steel spring hook for dipping; *B*. Rack and turntable; *C*. Magnetic fixture; *D*. Mechanical fixture; *E*. Improved mechanical fixture—the one finally adopted.

that used for spraying the inside. The box covers were again baked in the oven for one and one-half hours and, when removed and cooled, were ready for the final inspection.

**Improved Methods.** These methods were tried in the order indicated on the following pages:



**1. Steel Spring Hooks.** It was apparent that considerable savings could be made if a way could be devised that would permit the operator to spray both the inside and the outside of the box cover or bottom in a single operation.

Several designs of spring hooks, similar to those used for another type of container, which held the piece from the inside were tried.

*Results.* It was found that the blast from the air gun would blow the piece from the hook. Hooks made from stiffer spring made hooking too difficult for girl operators. This method was discarded as impractical.

**2. Dipping in Enamel.** Since some products were being satisfactorily dipped in enamel and baked in a continuous oven it was suggested that an attempt be made to dip the boxes. Wire hangers, like *A* shown in Fig. 57, were made and dipping was tried.

*Results.* An air pocket formed in the upper corner of the box covers which prevented the enamel from making contact with the metal. Also the enamel failed to drain out of the lower corner properly. The device for dipping the boxes was discarded.

**3. Spray Outside on Turntable.** The box covers were sprayed on the inside in the old manner and placed on a narrow tray *B* shown in Fig. 57. When seven box covers had been placed on the tray the out-sides of all of them were sprayed and the trayful then sent to the oven for baking.

*Results.* The air from the spray gun blew the boxes off the rack. If heavy corrugations or teeth were cut in the edges of the tray, they disfigured the enamel finish on the boxes. This method was discarded.

**4. Magnetic Fixture.** A permanent magnet *C* shown in Fig. 57 was used to hold the box cover while the operator sprayed both the inside and the outside in one operation.

*Results.* This proved to be a satisfactory method for holding the cover, but it was difficult to get the sprayed pieces off the magnet to the screen tray. The suggestion was not used.

**5. Mechanical Fixture.** The fixture *D* shown in Fig. 57 was made so that the cover rested on three knife edges and was held mechanically in place with a needle point.

*Results.* This device was satisfactory in that it permitted the inside and outside of the cover to be sprayed at one operation, and it was easy to release the piece and dispose of it on the screen tray. However, the two knife edges tended to scrape the enamel off the edges of the cover as it slid off the holder in disposing of it onto the screen tray.



**6. Improved Mechanical Fixture.** The holder *E* shown in Fig. 57 was built with two parallel knife edges so that they did not scrape off the enamel in disposing of the sprayed cover.

*Results.* This fixture proved to be entirely satisfactory, and several were made of aluminum and immediately put into use on production work. Each operator is supplied with two fixtures, allowing one to soak in solvent while the other one is being used.

The improved method, using this fixture, proved to be superior to the old method in the following ways:

1. The operator now sprays both the inside and the outside of the box cover or bottom at one operation. This effects a saving of approximately 25 per cent in direct labor.
2. The covers and bottoms are baked only once instead of twice. This reduces the use of the baking ovens 50 per cent and also reduces the indirect labor for handling racks and trays 50 per cent.
3. An additional saving results in that the investigation showed that the inside of the box covers and bottoms were being sprayed with a dull-finish enamel and the outside with a glossy-finish enamel. As there is no need for the dull finish on the inside and since dull-finish enamel is more expensive than glossy, use of the dull has been discontinued and the entire box sprayed with glossy enamel. This alone has saved in one year more than enough to pay for all the experimental fixtures that were used in the development work.

**Clean-up Work.** Janitor or clean-up work represents a sizable part of the office and factory pay roll. For example, the wages paid for clean-up work in the Ford Motor Company run into millions of dollars per year with more than 5000 men employed on this kind of work. In some organizations such work accounts for as much as 10 to 15 per cent of the total wages.

In discussing this subject Lawrence A. Flagler formerly of the Procter and Gamble Company states, "A survey of our factory clean-up costs revealed the fact that clean-up represented one of the largest single classifications of wage expense. It showed that there were more than 700 people in the Company engaged in this kind of work. . . . It is my estimate that there are at least 150,000 full-time factory clean-up men employed in this country."<sup>1</sup>

<sup>1</sup> Lawrence A. Flagler, "Motion Study Applied to Factory Clean-Up." *Abstract of Papers Presented at the Management Conference, University of Iowa, March 31, 1939, Extension Bulletin 458, p. 9.*



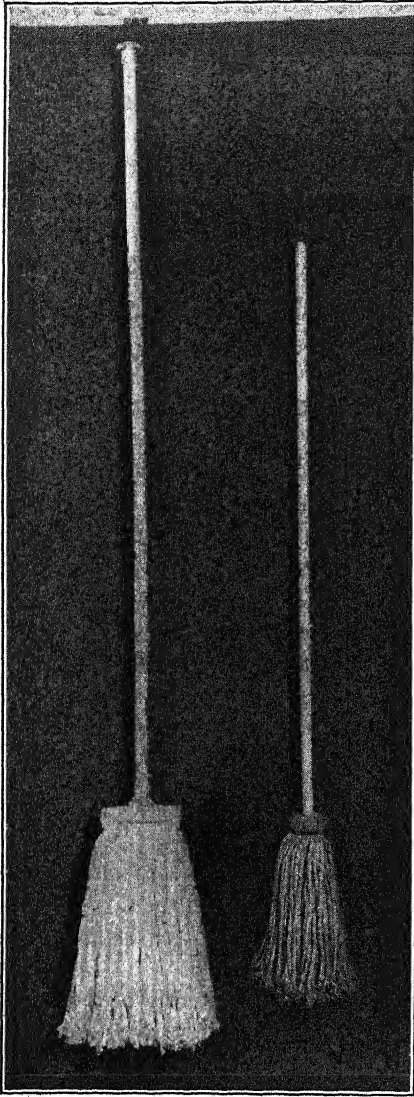


FIG. 58. Two common types of mops.  
A. "Head" mop on the left; B. "Ferrule"  
mop on the right.

Some of the results of a careful study of cleaning tools and equipment and of clean-up methods made by one organization are given here. They show what may be accomplished by setting out to answer such a single question as (see III-1, page 80) "Are the tools the best kind for this work?" Although these findings apply to conditions in this particular concern, many of the results of this investigation are basic and have wide application.

The first step was to find the best equipment. Since the tools that the janitor uses cost but a few dollars per year and since they represent less than two-tenths of one per cent of the total clean-up costs, it is false economy to purchase any but the most efficient tools.

**Cleaning with Mop.** Mopping of floors is one of the important classes of janitor work. Of the 700 people on clean-up work at Procter and Gamble's, for example, the equivalent of 215 of these people spend their full time mopping floors.

An analysis of the operations used in mopping floors indicated that the following factors were most important in the selection of a mop:

1. High ratio of water absorption to give maximum transfer of water to and from the floor for each stroke of the mop.
2. Minimum retention of water in the mop after wringing in order to reduce the dead weight and its corresponding higher fatigue allowances.



3. The shape of the mop to provide maximum surface contact between the mop and the floor.
4. Minimum weight of handle, hardware, or fixtures.
5. The wearing qualities of the mop.

**Specifications for a Mop.** Factory tests made of more than forty different styles and kinds of mops resulted in the following specifications for a good mop:

1. Mops should be of wide tape type to be used with detachable handles.
2. The mop should be made of a good grade of 4-ply, soft roving, long staple yarn free from linters and foreign material.
3. The length of the mop strands should be 38 to 42 inches, taped in the middle with good cotton duck at least 5 inches wide. The completed mop should be  $6\frac{1}{4}$  to  $6\frac{3}{4}$  inches in width after sewing on the tape with at least three rows of double stitching. The mop is not to be sewed in the folded shape in order that both sides may be used to equalize wear.
4. The average dry weight of the cotton should be  $23\frac{1}{2}$  to  $24\frac{1}{2}$  ounces for wet mopping and  $31\frac{1}{2}$  to  $32\frac{1}{2}$  ounces for dry mopping.
5. The mop handle should be 60 inches long,  $1\frac{1}{4}$  inches in diameter, and have an aluminum knob at the end.<sup>2</sup>
6. The mop attachment device should be of the claw or clamp type, wherein the mop is folded, placed in the open clamp, and the wing nut tightened. The hardware on the mop should be light in weight and made of rust-resisting material.

Figure 58 shows a good mop and a poor one. The "ferrule" mop on the right is unsatisfactory for factory work. The mop is too small, the handle is too short, and the ferrule where the mop is attached to the handle prevents the mop from lying flat on the floor.

The "head" mop on the left is well designed. The handle is long with a knob on the end. Because the head mop lies flat on the floor there is 30 per cent more cotton in contact with the floor than with a ferrule mop of equal weight. In addition the head mop fits the wringer better, and 10 per cent more water can be removed, making for faster pick-up of dirty water from the floor, less dead weight for the janitor to handle, and fewer wringing operations.

**Recommended Method of Mopping.** The recommended method for mopping is the use of the "side to side" stroke rather than the "push or pull" stroke. The janitor positions himself in the middle of the stroke length with his feet spread well apart and at right angles to the direction of the stroke (see Fig. 60). The mop handle is grasped

<sup>2</sup> When mopping in open unobstructed areas the mop stroke can be lengthened from 12 feet,  $1\frac{1}{2}$  inches, to 12 feet,  $10\frac{1}{2}$  inches, an increase of 6.9 per cent, by the use of a knob on the end of the regular handle.



over the end with one hand and approximately 15 inches down the handle with the other hand. The mop is placed flat on the floor and passed from side to side in front of the janitor in the form of an arc. The arc should be slight, as too wide an arc will greatly increase the effort required in that the arms are extended in front of the body at a lower muscular efficiency. The mop should pass in front of the janitor and within about 3 inches of his feet. At the ends of the stroke the mop is slightly looped to reverse the direction. Centrifugal force in describing the arc spreads the mop strands to increase the area covered in the stroke. Periodically, depending on the floor condition, the mop

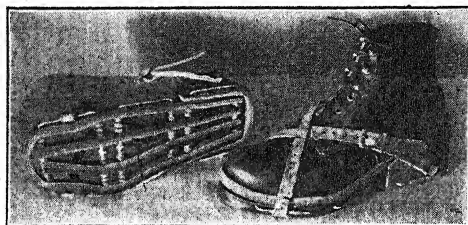


FIG. 59. Belting sandals. This simple device keeps the janitor's feet dry, helps prevent slipping, and increases output 5 per cent.

is flopped over to give an equal distribution of water and to use both sides of the mop effectively. As the boundary is approached, the janitor reverses his position 180 degrees at the end of the stroke, and with proper timing this motion can be accomplished with only a momentary loss of time. The optimum length of stroke for a janitor of average height is 12 feet, which with an effective width of 0.70 foot will result in a coverage of 8.4 square feet per stroke.

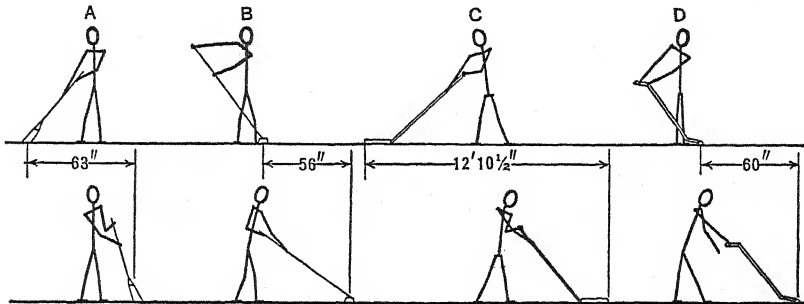
In planning the work, the direction of mopping should be arranged so that a full stroke can be used. For example, an  $11\frac{1}{2}$ -foot by 16-foot storage bay should be mopped with an  $11\frac{1}{2}$ -foot stroke perpendicular to the 16-foot dimension. As most factories have a uniform size of storage bay, it is possible for the janitor to standardize his starting position so as to use the optimum length of stroke. In mopping aisles the direction of the stroke should parallel the aisle. For example, a 32 per cent saving in time is possible when a 5-foot by 120-foot aisle is mopped with lengthwise instead of crosswise strokes. Another reason for parallel mopping of aisles is that splashing of the mop against the mop boards or materials in storage is minimized.

Much time is lost in transporting water in small buckets. A specially designed mop truck has been developed with three large



water compartments having a 42-gallon capacity for clean water and a 37-gallon capacity for dirty water. The temperature of the clean water should not get below 130° F. for effective use.

By wearing nonskid sandals similar to those shown in Fig. 59 the janitor is able to keep his feet dry, and there is less danger of slipping, which brings an increase in output of 5 per cent.



#### A. CLEANING WITH SWEEP BROOM

Length of Broom Handle 54 Inches

*At start of stroke:* Shoulder is normal, feet normal, and in a position for a forward step. Right arm is straight.

*At end of stroke:* Shoulder is turned 45 degrees, broom is just past vertical.

#### C. CLEANING WITH MOP

Length of Mop Handle 60 Inches

*At start of stroke:* Shoulder is turned 90 degrees to right with right arm at 45 degrees and down 14 inches on the handle. Weight is shifted to right foot with back inclined 4 inches to right. Left hand is grasping end of handle.

*At end of stroke:* Shoulder is turned 90 degrees to left with right arm at 45 degrees and down 14 inches on the handle. Weight is shifted to left foot with back inclined 4 inches to left. Left hand is grasping end of handle.

#### B. CLEANING WITH PUSH BRUSH

Length of Brush Handle 68 Inches

*At start of stroke:* Shoulder is turned 45 degrees, and right arm is horizontal.

*At end of stroke:* Shoulder is normal, feet positioned for normal step forward on return stroke. Left arm is straight at 45 degrees with vertical. Back is turned 45 degrees at hip.

#### D. CLEANING WITH VACUUM TOOL

Height of Tool above Floor 29 Inches

Length of Tool 56 Inches

*At start of stroke:* Shoulder is turned 90 degrees, right arm is at 45 degrees to back, and feet are together.

*At end of stroke:* Shoulder is normal, right arm is 45 degrees to front, and a forward step is taken.

FIG. 60. Description of recommended methods for using a broom, brush, mop, and vacuum cleaner.

Considering all the improvements of mopping methods and equipment made, the coverage is now 2000 square feet per man-hour in comparison with slightly less than 1000 square feet per man-hour previous to the installation of the improvements.

Although space does not permit detailed analysis and recommendations for each of the other tools that the janitor uses, brief reference will be made to a few of them.

**Cleaning with Push Brush.** The most effective tools and methods for sweeping floors will depend upon such factors as kind and amount



of dirt, kind of floor, kind and amount of obstructions, and the desired cleanliness of the floor. In general the following conclusions have been reached:

1. Push brushes made of Russian bristles are recommended for dry and light dirt.
2. Push brushes made of fiber are recommended for wet and heavy dirt.
3. Depending on the amount of obstruction, widths of brushes should vary from 18 to 36 inches.
4. Brush handles should be at least 68 inches long.
5. Corn brooms should never be used except for very special cases.

**Cleaning with Vacuum Tool.** One concern found that for its particular conditions a vacuum cleaner with a high-speed motor mounted

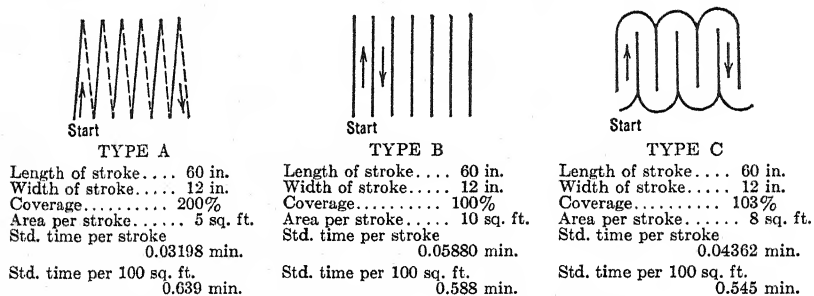


FIG. 61. Three types of vacuum-cleaner strokes. From the theoretical calculations shown above and from factory practice Type C was found to be most effective.

over a dust-collecting can on casters and with the filter exposed on the discharge side of the pump was most efficient. Studies showed that a cleaner tool 12 inches wide is most effective for areas with an average degree of obstruction. An aluminum handle with a double bend and a swivel at the point where the hose is fastened on to the vacuum cleaner is the best. The most efficient stroke was found to be looping the tool across the floor at the end of the stroke (see Fig. 61) rather than making an abrupt change in direction.

**Washing Windows.** In one plant windows were washed with wet rags, dried with chamois, and polished with a dry cloth. The method was changed to washing the windows with a wet sponge, drying with a squeegee, and cleaning the edges at the sash with a dry rag. The increase in production was from 316 panes, 13 by 10 inches, to 910 panes of the same size in a given length of time.



## CHAPTER 8

### MICROMOTION STUDY

Micromotion study provides a technique for recording and timing an activity. It consists of taking motion pictures of the operation with a clock in the picture or with a motion-picture camera operating at a constant and known speed. The film becomes a permanent record of both method and time and may be re-examined whenever desired.

**Purposes of Micromotion Study.** Micromotion study was originally employed for job analysis work, but in recent years new uses have been found for this valuable tool. Micromotion study may be used for the following purposes: as an aid in obtaining motion-time data for synthetic time standards, as a permanent record of the method and time employed in doing work, as an aid in studying the relationship of the activities of the operator and the machine, as an aid in studying the activities of two or more persons on group work, as a means of timing short-cycle operations (instead of using stop-watch time study), and for research in the field of motion and time study. However, as valuable as micromotion study is for the above purposes, the two most important uses for micromotion study are: (1) to assist in finding the most efficient method of doing work; and (2) to assist in training individuals to understand the meaning of motion study and, when the training is carried out with sufficient thoroughness, to enable them to become proficient in applying motion-economy principles.

It is essential that these two purposes of micromotion study be kept clearly in mind. Micromotion study might be of little value in many plants if it were used only as a means of determining methods for doing work. On the other hand, it might be highly profitable when used to train the factory or office personnel in the use and value of motion study.

**Micromotion Study as an Aid in Improving Methods.** Micromotion study provides a technique that is unequaled for making a minute analysis of an operation. As will be explained in detail later, the motion-picture film records the motions made and permits an examination of these motions. The film is projected on the screen, and the pictures are enlarged many times to facilitate the analysis of the



motions. The timing of each movement of the worker can be made to any degree of accuracy desired. With such a tool available it might be expected that its use would be universal. This, however, is not true, for a number of very good reasons.

First, micromotion study is not necessary in a large majority of the operations in the factory. One who understands the technique and the principles of motion study can, in most cases, visualize the operation completely and, by applying the principles that go to make good motion economy, determine methods that should be used. Motion study may be carried out in most cases without taking a motion picture and making the full analysis that micromotion study requires. Moreover, a micromotion study, although not prohibitive in cost, does require special motion-picture equipment, film, and considerable time for the analysis. Micromotion study for determining methods of doing work has a place in industry, although not so large a place as some maintain. This is the less valuable of the two main purposes of micromotion study.

Micromotion study should be treated as any tool—something to be used when it is profitable to do so. It might, for example, profitably be used in the investigation of short-cycle operations that are highly repetitive or largely manual in character, or of work produced in large volume or of operations performed by large numbers of workers. These factors alone do not always determine whether a micromotion study should be made or not. In fact, a micromotion study is often the last resort, the procedure that is used when the application of the principles of motion economy to the job does not seem to produce the desired results. Sometimes in a complex operation it is difficult to get the motions of the two hands balanced without the aid of the simo chart, which is the graphic picture of the motions on paper.

**Micromotion Study as an Aid in Teaching.** Industry has been slow to realize the fact that micromotion study is of greatest value in aiding one to understand motion study. From its definition motion study would appear to be very simple and easily understood. However, there is a knack to getting at the real meaning of it, and in being able to understand it in its entirety.

It is essential for the individual to become proficient in detecting and following the motions used by the worker in performing his task. He must *see* the motions made by the operator's right hand, by his left hand, even noting what the fingers of each hand do. It is necessary to be able to detect where one motion ends and another begins. As



the Gilbreths state, ". . . one must have studied motions and measured them until his eye can follow paths of motions and judge lengths of motions, and his timing sense, aided by silent rhythmic counting, can estimate times of motion with surprising accuracy. Sight, hearing, touch, and kinesthetic sensations must all be keenly developed."<sup>1</sup>

The term "motion-minded" has been used to describe this ability of the person who has trained himself to follow unconsciously the motions of the worker and check them against the principles of motion economy with which he is familiar. Micromotion study is of great assistance in training individuals to become motion-minded.

A person may have made stop-watch studies for years and yet not understand the real meaning of motion study. To have set time standards with a stop watch is no handicap in learning to apply motion-economy principles; it may be an asset. However, unless one understands the meaning of motion study he will be unable to practice time study in its fullest sense.

R. M. Blakelock once said, ". . . the greatest value of micromotion training comes through the ability to visualize industrial operations in terms of motions . . . the ability to visualize the motions that are necessary to perform each step of an operation, and to recognize which are and which are not good motion practice, rather than think in such terms as describe steps in the operation itself.

"Most time study observers, as they record steps in the operation, think in terms of elemental operations, such as 'drills one hole,' 'faces off side,' 'rivets end,' or 'assembles part 2 to part 3,' making no analysis of the motions of the operator, and giving little thought to them unless there is a glaring case of bad motions that is quite obvious."<sup>2</sup>

R. M. Blakelock, while in charge of the motion study division at the Schenectady plant of the General Electric Company, said that he seldom found it necessary to make a micromotion study to determine proper methods for doing work. He applied the principles of motion study without needing to resort to the use of the motion-picture camera. However, he did make extensive use of this technique for training members of the organization.

<sup>1</sup> F. B. and L. M. Gilbreth, "Applied Motion Study," p. 61, Sturgis & Walton, New York, 1917.

<sup>2</sup> R. M. Blakelock, "Micromotion Study Applied to the Manufacture of Small Parts," *Factory and Industrial Management*, Vol. 80, No. 4, pp. 730-732, October, 1930.



For information concerning the use of micromotion study by the Fort Wayne works of the General Electric Company and by other companies, see Chapter 28.

**Motion Pictures Not Micromotion Study.** As will be shown later, making a motion picture of an operation is not identical with making a micromotion study of it. The motion picture does, however, have some very interesting and valuable uses apart from micromotion study. This value comes through the ability to picture motions on the screen. One of the most recent uses of the camera has been to make pictures of the old method, and then of the method after it has been improved. Such "before" and "after" pictures provide an excellent means of selling an organization on the value of motion study. Then since motion pictures may be slowed down, speeded up, reversed, or stopped on the screen, they offer possibilities for familiarizing any group with work that might be difficult to describe. The motion picture furnishes a permanent record of work that is impossible to obtain in any other way. These several uses of the motion-picture camera have been discussed here to emphasize the fact that a motion picture, although valuable in itself, should not be confused with a micromotion study. The latter requires, in addition to the picture of the operation, a very accurate timing device and a full analysis of the motions used.



## CHAPTER 9

### FUNDAMENTAL HAND MOTIONS

Most work is done with the two hands, and all manual work consists of a relatively few fundamental motions which are performed over and over again. "Get" or "pick up" and "place" or "put down" are two of the most frequently used groups of motions. In most cases "get" is followed by some "use" or "process" element such as driving a nail with a hammer, using a wrench to tighten a bolt, or writing with a pen. In using a fountain pen the sequence of motions would be *get* pen, write, that is, *use* pen, *place* pen in holder. Although *get* and *place* represent two very common groups of motions, they are not fundamental motions in themselves.

Frank B. Gilbreth, in his early work in motion study, developed certain subdivisions<sup>1</sup> or events which he thought common to all kinds of manual work. He coined the word "therblig" (Gilbreth spelled backwards) in order to have a short word with which to refer to any of these seventeen elementary subdivisions of a cycle of motions.<sup>2</sup> Although these seventeen therbligs are not all pure or fundamental elements in the sense that they cannot be further subdivided, they are the best classification of hand motions that we have. The experienced analyst has no difficulty in using the therbligs in industrial applications.

The term therblig is more convenient to use than "hand motion" or "motion element" and perhaps carries a more precise meaning than the term "motion." Although the word therblig has wide use among industrial engineers, the term motion or hand motion is preferred when discussing the subject of micromotion study with factory and office

<sup>1</sup> Certain European investigators have used other subdivisions of work. See R. Thun, "Work Studies with the Help of the Cinematograph," *International Review of Educational Cinematography*, Vol. 2, No. 7-8, pp. 849-885, July-August, 1930. For the therbligs used by others, see "Production Handbook," L. P. Alford and J. R. Bangs (Eds.), p. 611, Ronald Press Co., New York, 1944. See also W. G. Holmes, "Applied Time and Motion Study," p. 217, Ronald Press Co., New York, 1938.

<sup>2</sup> F. B. and L. M. Gilbreth, "Classifying the Elements of Work," *Management and Administration*, Vol. 8, No. 2, p. 151, August, 1924.



personnel. Uncommon terms and symbols (such as the mnemonic therblig symbols) may be a handicap in a training program and are to be avoided whenever possible.



































Name of Symbol	Therblig Symbol	Explanation-suggested by	Color	Color Symbol	Dixon Pencil Number	Eagle Pencil Number
Search	Sh 	Eye turned as if searching	Black		331	747
Select	St 	Reaching for object	Gray, light		399	734½
Grasp	G 	Hand open for grasping object	Lake red		369	744
Transport empty	TE 	Empty hand	Olive green		391	739½
Transport loaded	TL 	A hand with something in it	Green		375	738
Hold	H 	Magnet holding iron bar	Gold ochre		388	736½
Release load	RL 	Dropping content out of hand	Carmine red		370	745
Position	P 	Object being placed by hand	Blue		376	741
Pre-position	PP 	A nine-pin which is set up in a bowling alley	Sky-blue		394	740½
Inspect	I 	Magnifying lens	Burnt ochre		398	745½
Assemble	A 	Several things put together	Violet, heavy		377	742
Disassemble	DA 	One part of an assembly removed	Violet, light		377	742
Use	U 	Word "Use"	Purple		396	742½
Unavoidable delay	UD 	Man bumping his nose, unintentionally	Yellow ochre		373	736
Avoidable delay	AD 	Man lying down on job voluntarily	Lemon yellow		374	735
Plan	Pn 	Man with his fingers at his brow thinking	Brown		378	746
Rest for overcoming fatigue	R 	Man seated as if resting	Orange		372	737

FIG. 62. Standard symbols and colors for fundamental hand motions.

The seventeen fundamental hand motions together with their letter symbols, mnemonic symbols, and color designations<sup>3</sup> are shown in Fig. 62. The definitions of these motions are given on the following pages.

<sup>3</sup> The color symbols are included in order to indicate color on the printed simo charts in this book. These color symbols should *not* be used in the actual construction of simo charts. Colored pencils should be used instead.



### Definition of Fundamental Hand Motions

#### 1. Search (Sh).

*Search* refers to that part of the cycle during which the eyes or the hands are hunting or groping for the object. Search begins when the eyes or hands begin to hunt for the object and ends when the object has been found.

The original list of the Gilbreth motions contained the therblig *find*. However, since *find* occurs at the end of the therblig *search*, and since it is a mental reaction rather than a physical movement, it is seldom used in micromotion analysis work. Therefore *find* is being omitted from the list of fundamental hand motions here.

#### 2. Select (St).

*Select* refers to the choice of one object from among several. In many cases it is difficult if not impossible to determine where the boundaries lie between *search* and *select*. For this reason it is often the practice to combine them, referring to both as the one therblig *select*.

Using this broader definition, *select* then refers to the hunting and locating of one object from among several. *Select* therefore begins when the eyes or hands begin to hunt for the object and ends when the desired object has been located.

*Example.* Locating a particular pencil in a box containing pencils, pens, and miscellaneous articles.

#### 3. Grasp (G).

*Grasp* refers to taking hold of an object, closing the fingers around it preparatory to picking it up, holding it or manipulating it. *Grasp* begins when the hand or fingers first make contact with the object and ends when the hand has obtained control of it.

*Example.* Closing the fingers around the pen on the desk.

#### 4. Transport Empty (TE).

*Transport Empty* refers to moving the empty hand in reaching for an object. It is assumed that the hand moves without resistance toward or away from the object. *Transport empty* begins when the hand begins to move without load or resistance and ends when the hand stops moving.

*Example.* Moving the empty hand to grasp a pen on the desk.

#### 5. Transport Loaded (TL).

*Transport Loaded* refers to moving an object from one place to another. The object may be carried in the hands or fingers or it may be moved from one place to another by sliding, dragging, or pushing it



along. Transport loaded also refers to moving the empty hand against resistance. Transport loaded begins when the hand begins to move an object or encounter resistance and ends when the hand stops moving.

*Example.* Carrying the pen from the desk set to the letter to be signed.

#### 6. Hold (H).

*Hold* refers to the retention of an object after it has been grasped, no movement of the object taking place.<sup>4</sup> Hold begins when the movement of the object stops and ends with the start of the next therblig.

*Example.* Holding bolt in one hand while assembling a washer on to it with the other.

#### 7. Release Load (RL).

*Release Load* refers to letting go of the object. Release load begins when the object starts to leave the hand and ends when the object has been completely separated from the hand or fingers.

*Example.* Letting go of the pen after it has been placed on the desk.

#### 8. Position (P).

*Position* consists of turning or locating an object in such a way that it will be properly oriented to fit into the location for which it is intended. It is possible to position an object during the motion *transport loaded*. The carpenter, for example, may turn the nail into position for using while he is carrying it to the board into which it will be driven. Position begins when the hand begins to turn or locate the object and ends when the object has been placed in the desired position or location.

*Example.* Lining up a door key preparatory to inserting it in the keyhole.

#### 9. Pre-position (PP).

*Pre-position* refers to locating an object in a predetermined place or locating it in the correct position for some subsequent motion. Pre-position is the same as *position* except that the object is located in the approximate position that it will be needed later. Usually a holder, bracket, or special container of some kind is used for holding the object in a way that permits it to be grasped easily in the position in which it will be used. *Pre-position* is the abbreviated term used for *pre-position for the next operation*.

<sup>4</sup> Gilbreth did not classify hold as a separate therblig but considered it a form of grasp.



*Example.* Locating or lining up the pen above the desk set holder prior to releasing it. (The pen may then be grasped in approximately the correct position for writing. This eliminates the therblig position that would be required to turn the pen to the correct writing position if it were resting flat on the desk when grasped.)

10. Inspect (I).

*Inspect* consists of examining an object to determine whether or not it complies with standard size, shape, color, or other qualities previously determined. The inspection may employ sight, hearing, touch, odor, or taste. *Inspect* is predominantly a mental reaction and may occur simultaneously with other therbligs. *Inspect* begins when the eyes or other parts of the body begin to examine the object and ends when the examination has been completed.

*Example.* Visual examination of pearl buttons in the final sorting operation.

11. Assemble (A).

*Assemble* consists of placing one object into or on another object with which it becomes an integral part. *Assemble* begins as the hand starts to move the part into its place in the assembly and ends when the hand has completed the assembly.

*Example.* Placing cap on mechanical pencil.

12. Disassemble (DA).

*Disassemble* consists of separating one object from another object of which it is an integral part. *Disassemble* begins when the hand starts to remove one part from the assembly and ends when the hand has separated the part completely from the remainder of the assembly.

*Example.* Removing cap from mechanical pencil.

13. Use (U).

*Use* consists of manipulating a tool, device, or piece of apparatus for the purpose for which it was intended. *Use* may refer to an almost infinite number of particular cases. It represents the motion for which the preceding motions have been more or less preparatory and for which the ones that follow are supplementary. *Use* begins when the hand starts to manipulate the tool or device and ends when the hand ceases the application.

*Example.* Writing one's signature in signing a letter (use pen) or painting an object with spray gun (use spray gun).

14. Unavoidable Delay (UD).

*Unavoidable Delay* refers to a delay beyond the control of the operator. *Unavoidable delay* may result from either of the following causes:



(A) A failure or interruption in the process.

(B) A delay caused by an arrangement of the operation which prevents one part of the body from working while other body members are busy.

Unavoidable delay begins when the hand stops its activity and ends when activity is resumed.

*Example.* If the left hand made a long transport motion to the left and the right hand simultaneously made a very short transport motion to the right, an unavoidable delay would occur at the end of the right-hand transport in order to bring the two hands into balance.

#### 15. Avoidable Delay (AD).

*Avoidable Delay* refers to any delay of the operator for which he is responsible and over which he has control. It refers to delays which the operator may avoid if he wishes.

Avoidable delay begins when the prescribed sequence of motions is interrupted and ends when the standard work method is resumed.

*Example.* The operator stops all hand motions.

#### 16. Plan (Pn).

*Plan* refers to a mental reaction which precedes the physical movement, that is, deciding how to proceed with the job. Plan begins at the point where the operator begins to work out the next step of the operation and ends when the procedure to be followed has been determined.

*Example.* An operator assembling a complex mechanism, deciding which part should be assembled next.

#### 17. Rest for overcoming fatigue (R).

*Rest for overcoming fatigue* is a fatigue or delay factor or allowance provided to permit the worker to recover from the fatigue incurred by his work. Rest begins when the operator stops working and ends when work is resumed.

**Motions Used in Signing a Letter.** It is a relatively easy matter to learn the names of these fundamental motions. For example, in signing a letter, the sequence of motions is *transport empty* (reach for pen), *grasp* (take hold of pen), *transport loaded* (carry pen to paper), *position* (place pen on paper at correct position for writing), *use* (sign letter), *transport loaded* (return pen to holder), *pre-position* (position pen in holder), *release load* (let go of pen), and *transport empty* (move hand back to letter). These motions are fully defined and illustrated on the next three pages.



## FUNDAMENTAL MOTIONS USED IN SIGNING A LETTER

## Motions of the Right Hand



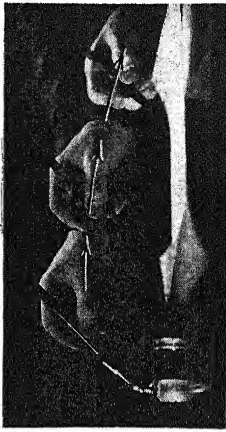
Name and Definition of Motion		Symbol	Description of Motion	Illustration
1	<b>TRANSPORT EMPTY</b> (Transport Empty refers to moving the empty hand in reaching for an object. It is assumed that the hand moves without resistance toward or away from the object. Transport empty begins when the hand begins to move without load or resistance and ends when the hand stops moving.)	TE	Reach for pen.	
2	<b>GRASP</b> (Grasp refers to taking hold of an object, closing the fingers around it preparatory to picking it up, holding it or manipulating it. Grasp begins when the hand or fingers first make contact with the object and ends when the hand has obtained control of it.)	G	Take hold of pen - close thumb and fingers around pen.	
3	<b>TRANSPORT LOADED</b> (Transport Loaded refers to moving an object from one place to another. The object may be carried in the hands or fingers or it may be moved from one place to another by sliding, dragging, or pushing it along. Transport loaded also refers to moving the empty hand against resistance. Transport loaded begins when the hand begins to move an object or encounter resistance and ends when the hand stops moving.)	TL	Carry pen to paper.	

FIG. 63.



## FUNDAMENTAL MOTIONS USED IN SIGNING A LETTER (Continued)


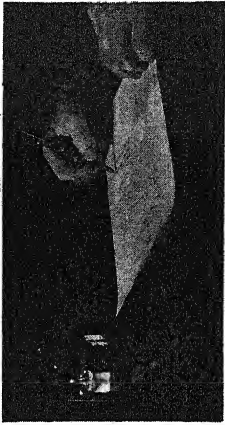

Name and Definition of Motion		Symbol	Description of Motion	Illustration
4	<b>POSITION</b> (Position consists of turning or locating an object in such a way that it will be properly oriented to fit into the location for which it is intended. It is possible to position an object during the motion transport loaded. The carpenter, for example, may turn the nail into position for using while he is carrying it to the board into which it will be driven. Position begins when the hand begins to turn or locate the object and ends when the object has been placed in the desired position or location.)	P	Position pen on paper for writing.	
5	<b>USE</b> (Use consists of manipulating a tool, device, or piece of apparatus for the purpose for which it was intended. Use may refer to an almost infinite number of particular cases. It represents the motion for which preceding motions have been more or less preparatory and for which the ones that follow are supplementary. Use begins when the hand starts to manipulate the tool or device and ends when the hand ceases the application.)	U	Sign letter.	
6	<b>TRANSPORT LOADED</b>	TL	Return pen to holder.	

FIG. 63 (Continued).



## FUNDAMENTAL MOTIONS USED IN SIGNING A LETTER (Continued)




Name and Definition of Motion	Symbol	Description of Motion	Illustration
<b>7 PRE - POSITION</b> (Pre-position refers to locating an object in a predetermined place or locating it in the correct position for some subsequent motion. Pre-position is the same as position except that the object is located in the approximate position that it will be needed later. Usually a holder, bracket, or special container of some kind is used for holding the object in a way that permits it to be grasped easily in the position in which it will be used. Pre-position is the abbreviated term used for pre-position for the next operation.)	PP	Position pen in holder.	
<b>8 RELEASE LOAD</b> (Release Load refers to letting go of the object. Release load begins when the object starts to leave the hand and ends when the object has been completely separated from the hand or fingers.)	RL	Let go of pen.	
<b>9 TRANSPORT EMPTY</b>	TE	Move hand back to letter.	

FIG. 63 (Continued).



**Motions Used in Removing the Cap from a Mechanical Pencil.** In order to obtain further practice in learning the fundamental motions, a chart (Fig. 64) is included showing the motions used in picking up a mechanical pencil from a tray, removing the cap from the pencil, and examining the pencil to see whether the eraser needs renewing.

Notice that in this case for the left hand there is a *select* following the transport empty and preceding the grasp. *Select* refers to the choice of one object from among several. In removing the fountain pen from the holder (see page 75) there was but one pen present, consequently, there was no selection required. In the second case the mechanical pencil was located in a box along with other pencils, and consequently the particular pencil desired was *selected* from the others.

*Hold* denotes the retention of the object after it has been grasped, no movement of the object taking place. *Unavoidable delay* refers to a delay beyond the control of the operator. *Disassemble* consists of separating one object from another object of which it is an integral part. *Inspect* consists of testing a piece to determine whether or not it complies with standard size, shape, color, or other qualities previously determined. Inspection may employ sight, hearing, touch, odor, or taste. Inspection is predominantly a mental reaction and may occur simultaneously with other motions. *Assemble* consists of placing one object into or on another object with which it becomes an integral part.

**Pinboard.** It seems natural for most people when observing another person at work to notice the material being handled or the tools being used rather than to observe the motions made in performing the task. After one becomes "motion-minded," that is, after one has learned the classification of hand motions, this situation is changed. The observer then notices the motions made with the right hand and those made with the left hand and then proceeds to use those motions which are easy and effective and to discard the awkward, fatiguing, and ineffective motions. Those people who accomplish the most do not necessarily work hardest. Rather, they make every motion count—they use good work methods. We are not at all interested in the "speed up" or "stretch out." We are interested in getting more quality work done with less expenditure of energy. Excessive speed is no substitute for good work methods.

To illustrate what is meant by developing a better method through the analysis of hand motions and the application of principles of motion economy, let us consider the task of filling a board contain-



ing thirty holes with thirty wooden pins. You will notice that there are five rows of six holes to a row in the board. (See Fig. 65.) The pins are square on one end and bullet-shaped on the other. The job is to fill the board with the pins as quickly as possible, inserting the pin in the hole with the bullet nose down.

Ninety-five people out of a hundred would fill the board using the method shown in Fig. 65. The left hand grasps a handful of pins from the box and holds them while the right hand gets pins from the left, one at a time, and places them in the board. The right hand is working in a very effective manner inasmuch as it is performing the desired task, that is, filling the board with pins. However, notice that the left hand is doing very little productive work. Most of the time it is merely holding the pins.

If both hands were to work simultaneously getting and placing the pins in the holes, the operator's efforts would be much more effective. Incidentally, we are now applying one of the "principles of motion economy" which will be presented later (page 191). We are having a preview of one of these principles now.

Using this improved method it is obvious that the left-hand "hold" has been eliminated, and instead the left hand like the right now performs useful motions. The two hands work together in a symmetrical manner getting the pins and placing them in the holes in the board. (See Fig. 66.)

*Results.* It requires approximately 0.62 minute to fill the board using the one-handed method, whereas but 0.41 minute is required to fill the board using the two-handed method. This represents a saving of 34 per cent in time.

The fundamental motions of the left hand in filling the pinboard are illustrated on pages 108 and 109.





FIG. 65. Inserting pins in board, using the one-handed method. Left hand *holds* pins, right hand works productively. It takes .62 minute to fill the board.





FIG. 66. Inserting pins in board, using simultaneous motions, both hands working together. It takes but .41 minute to fill the board using this method.



## FUNDAMENTAL MOTIONS USED IN INSERTING PIN IN PINBOARD

The operator is using simultaneous symmetrical motions in filling the pin-board. (See Fig. 66.) Since the motions of the left hand and the right hand are the same, the motions of the left hand only will be shown here.

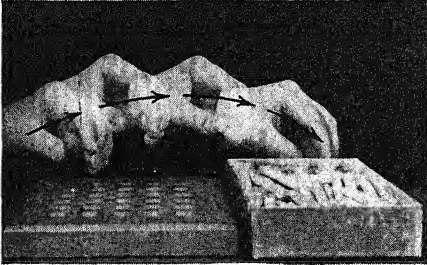
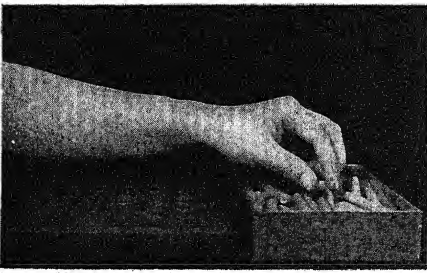

Illustration	Name of Motion	Symbol
	<p><b>TRANSPORT EMPTY</b></p> <p>Reach for pin.</p>	<p>TE</p>
	<p><b>SELECT</b></p> <p>Select one pin from among those in box. The eyes aid the hand in searching for a particular pin. This searching and then spotting or finding a particular pin is called <u>select</u>.</p>	<p>St</p>
	<p><b>GRASP</b></p> <p>Close thumb and fingers around the pin selected.</p>	<p>G</p>

FIG. 67.



FUNDAMENTAL MOTIONS USED IN INSERTING PIN IN PINBOARD  
(Continued)

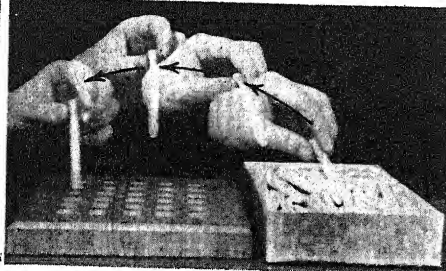
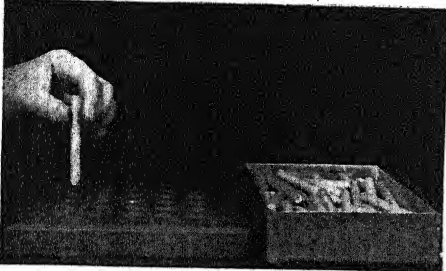
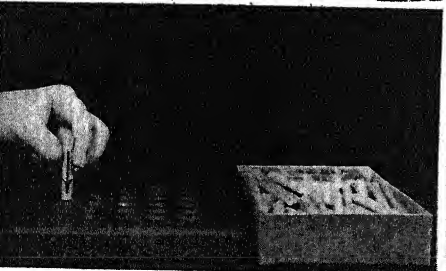
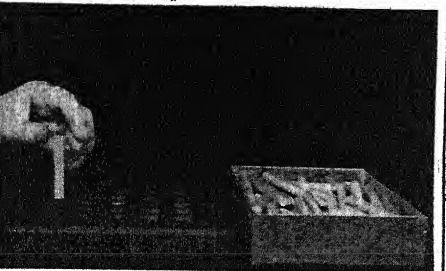
Illustration	Name of Motion	Symbol
	<p><b>TRANSPORT LOADED</b></p> <p>Carry pin from tray to hole in board into which it will be inserted.</p> <p>Also: <b>POSITION (in transit)</b></p> <p>Pin is turned into vertical position as it is transported to board.</p>	<p>TL</p> <p>P</p>
	<p><b>POSITION</b></p> <p>Pin is lined up directly over the hole in the board into which it is to be inserted.</p>	<p>P</p>
	<p><b>ASSEMBLE</b></p> <p>Insert pin into hole in board.</p>	<p>A</p>
	<p><b>RELEASE LOAD</b></p> <p>Open fingers - let go of pin.</p>	<p>RL</p>

FIG. 67 (Continued).



## CHAPTER 10

### MOTION STUDY AND MICROMOTION STUDY EQUIPMENT

The motion-picture camera is the most important piece of equipment used in motion study and micromotion study work.<sup>1</sup> The first cameras were of the hand-cranked type, using 35-mm. width film. The camera was mounted on a tripod and fitted to take either single exposures or pictures at varying speeds up to 100 frames per second or faster.

Today the professional camera using 35-mm. film has entirely given way to the amateur motion-picture camera using 16-mm. or 8-mm. film for motion study work. Although 8-mm. equipment has been used to a limited extent for motion study work, there is a definite trend toward the standardization of 16-mm. equipment in this field.

**Spring-Driven Camera.** The typical amateur motion-picture camera is very compact and light in weight. It is operated by a spring-driven motor which runs approximately one-half minute with one winding. The speed with which the film passes through the camera is regulated by a governor which maintains a constant speed (within plus or minus 10 per cent) until the spring motor runs down and stops. Some camera motors slow down sharply near the end of their "run" and need more frequent windings if an approach to a uniform speed is to be maintained.

The typical camera can be loaded or unloaded in the daylight, and takes either a 50-foot or a 100-foot roll of film. The normal speed is sixteen exposures per second. A 100-foot roll of film, exposed at normal speed, will last approximately four minutes. Although the amateur spring-driven camera may be operated satisfactorily for most kinds of out-of-door work without the use of a tripod, for motion study work a tripod is necessary.

Since there are a number of excellent cameras on the market suitable for motion study work, no attempt will be made to describe them here. However, a motion-picture camera should have at least the following features if it is to be used satisfactorily for micromotion study work:

<sup>1</sup> The cyclegraph, the kymograph, and the automatic time recorder are used for research work in this field.



1. Lens— $f.2.4$  or faster;  $f.1.9$  is preferred.
2. Focus—adjustable—from 4 feet or closer to infinity (a camera with a fixed focus lens is not satisfactory).
3. Film capacity—100 feet.
4. Accurate film meter.

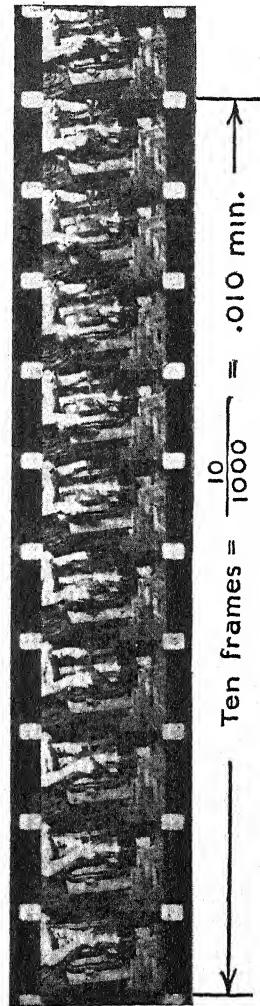
The following additional features are desirable but not absolutely necessary:

5. Variable-speed spring motor which operates from one-half normal speed (8 frames per second) to four times normal speed (64 frames per second).
6. Interchangeable lenses.
7. Electric motor drive attachment.

**Electric Motor-Driven Camera.** Some use is being made of motion-picture cameras driven by a constant-speed electric motor. (See Fig. 236 on page 336.) The most common speed for an electric motor-driven camera is 1000 frames per minute. This speed is slightly faster than normal speed, which is 16 frames per second or 960 per minute. Camera speeds other than 1000 frames per minute may be obtained by changing the gear ratio between the motor and the camera.

An enlarged print from a strip of film made at a speed of 1000 frames per minute is shown in Fig. 68. The time interval that elapsed from one frame to the next on this film was exactly  $\frac{1}{1000}$  of a minute. The motions of the hand shown as taking place during the exposure of the 10 frames reproduced in Fig. 68 required  $\frac{10}{1000}$  of a minute (0.010).

Since the camera operates at a constant and known speed, the microchronometer (see Fig. 69) is not needed to indicate time on the film. Furthermore, it does not occupy valuable space in the picture nor shut out motions of the operator being studied. It is easy to assign time values to the motions since no study need be made of the position of the clock's hands. If the film is projected on a screen it is pos-



(Film 16-mm. in width, enlarged  $\frac{1}{2}$ .)

FIG. 68. Motion-picture film made with constant-speed motor-driven camera. This strip of film shows part of a counter-boring operation on a drill press.



sible to know the exact projection speed by means of a tachometer attached to the projector. (See Fig. 286 on page 474.) In other words, one can project the film on the screen at exactly the same speed at which it was made, or at a faster or slower speed of known value.

Although the electric motor-driven camera has certain advantages, a good amateur motion-picture camera of the regular spring-driven type is perfectly satisfactory for all ordinary motion study and micromotion study work.

**Camera Speeds.** The amateur motion-picture camera operates in such a way that one frame, or the film for one exposure, is suddenly "pulled down" or jerked in front of the lens of the camera during an instant when the camera shutter has closed the lens. After the film is in place, the rotating shutter opens and permits the subject to be photographed. The shutter then closes and the next frame is pulled down for the next exposure, and so on. The shutter is closed one-third to one-half of the time (depending on the design of the shutter) that the camera is in action. The ratio of the size of the open segment in the shutter to the closed segment determines the exposure time for one rotation of the shutter. The shutter makes one complete revolution each time an exposure is made. Therefore, if the camera is operating at the normal speed of 16 exposures per second, and the camera has a shutter with an open segment of 180 degrees, the time that the lens will be open during one revolution is  $\frac{1}{16} \times \frac{180}{360}$  or  $\frac{1}{32}$  of a second.

The motion-picture camera photographs intermittent scenes. In photographing moving subjects there is an instant ( $\frac{1}{32}$  of a second in the above case) between successive exposures during which no record of action that has been taking place is made on the film. It is for this reason that successive frames on the film show the moving object at different points along its line of motion (see enlarged print in Fig. 78). The hand reaching for an object is shown first a foot away from the object, then 10 inches, then 8 inches, etc. Where the movement of the subject is relatively rapid, the moving object appears to be blurred. The right hand in Fig. 84 appears blurred in exposures 2, 7, and 8. This blur is due to the fact that during the short instant when the shutter was open the hand moved a sufficient distance to cause the blur. These blurs are eliminated by exposing the film at a more rapid rate. Had the picture been made at 32 instead of 16 exposures per second, the time during which the shutter remained open would have been but  $\frac{1}{64}$  of a second, and the hand would have moved but one-half the distance. This would have reduced or entirely eliminated the blur.



With the camera operating at normal speed, it frequently happens that the hand, for example, changes direction entirely, while the shutter is closed. If an operator should reach for an object, the hand might be shown moving to the right on one frame of the film. On the next frame it might be shown moving to the left. During the instant that the shutter was closed the hand had actually continued to move to the right, grasped a piece of material, and was on its return movement when the next exposure was made. For very accurate studies such hidden motions are undesirable. To prevent this it is necessary to operate the camera at higher speeds.

Although the camera normally operates at a speed of 16 exposures per second, amateur spring-driven cameras are available which operate at speeds as high as four times normal.<sup>2</sup>

For ordinary micromotion study work the normal camera speed is satisfactory. For studying rapid hand motions it may become necessary to use twice normal speed, and in evaluating very short and fast motions such as a "sliding grasp," under laboratory conditions, speeds of 5000 exposures per minute or higher may be required.

**Motion Pictures Are Easy to Make.** The amateur motion-picture camera is designed so that the average person is able to make satisfactory pictures without practice. However, pictures inside the factory for motion study work are more difficult to make than out-of-door pictures. Most people are able to make very satisfactory pictures by following the directions which come with the camera. Even though a person may be able to make successful pictures of the ordinary factory operations, it will be to his advantage to learn as much about photography as he can.<sup>3</sup>

A motion-picture data sheet similar to the one shown on page 126 is of real assistance in improving one's ability to take good pictures under widely varying conditions. This data sheet provides a permanent record of all important factors connected with the taking of the pictures. The information on this sheet may be used as a check if pictures do not turn out satisfactorily, or as a reference if pictures are to be made under new conditions. The mere necessity of record-

<sup>2</sup> Professor H. E. Edgerton has taken still photographs with an exposure of a millionth of a second and has taken motion pictures at 6000 exposures a second. See H. E. Edgerton, J. K. Germeshausen, and H. E. Grier, "High Speed Photographic Methods of Measurement," *Journal of Applied Physics*, Vol. 8, No. 1, p. 1, January, 1937.

<sup>3</sup> "How to Make Good Movies," Eastman Kodak Co., Rochester, N. Y.



ing the various items on the data sheet, such as diaphragm opening, focus, distance of the subject from the camera, number of spotlights used, automatically prevents the beginner from making the picture before he has adjusted his camera and completed his setup. The greatest value of using such a data sheet, as will be explained more fully in the next chapter, is that it together with the film number forms a permanent record for completely identifying any piece of film.

**Microchronometer.** Since the number of exposures made on the film in any given time interval will depend upon the speed of the

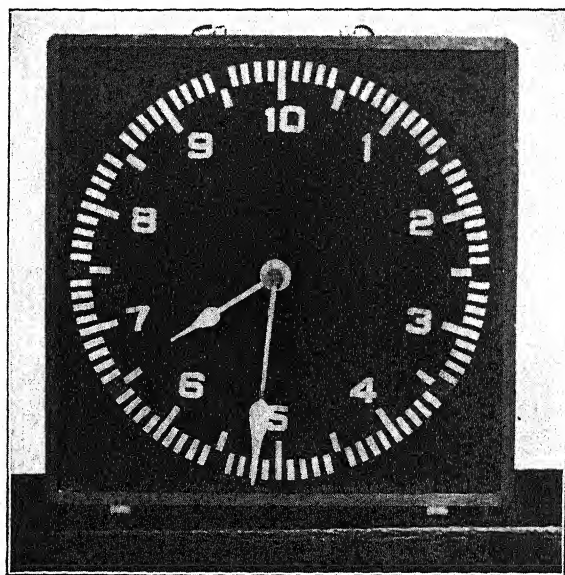


FIG. 69. Electric motor-driven microchronometer. The large hand makes 20 revolutions per minute and the small hand makes 2.

camera, and since the speed of a spring-driven camera is neither known nor constant, it is necessary to place some very accurate timing device in the picture so that the time interval from the exposure of one frame to the exposure of the next will be indicated on the film.

Gilbreth developed a spring-driven, fast-moving clock, called a microchronometer, capable of indicating time to  $\frac{1}{2000}$  of a minute. The dial of the clock was divided into 100 equal spaces and the hand made 20 revolutions per minute. Synchronous motor-driven clocks are now used. Such clocks are very accurate, and the hands may be



geared to indicate time intervals of any desired length. The clock shown in Fig. 69 is driven by a small synchronous motor. It has 100 equal divisions on the dial, the large hand makes 20 revolutions per minute, and the small hand 2 revolutions per minute. Each division on the dial indicates  $\frac{1}{2000}$  of a minute. The clock reading in Fig. 69 is 652. By changing the gear ratio inside the clock, the large hand will make 50 revolutions per minute and the small hand 5. By using this latter arrangement it is possible to read time intervals of  $\frac{1}{5000}$  of a minute without interpolation. The clock is operated at this fast speed only when the film is exposed at 2000 frames per minute or faster.

When the electric motor-driven camera is used, the microchronometer is not needed unless it is wanted for the purpose of quickly identifying particular motions or places in a cycle. It is sometimes used for this purpose.

**Illumination.** In so far as possible, motion pictures should be made by daylight. Frequently some additional illumination is required. Such illumination is easily provided by portable spotlights or "photo-flood" lamps fitted with a suitable reflector and supported by a tripod. With either the standard spotlight or the photoflood lamp, the problem of lighting the subject to be photographed is easily solved. Ordinarily two light sources should be used for best results. The lamps should be placed so that the work place and the particular motions to be studied are properly lighted without deep shadows. If the person making the picture remembers that he is later going to study the motions in detail, he will be more likely to see that the motions are properly lighted.

With the development of "supersensitive" motion-picture film the need for artificial lighting has been reduced.

**Laboratory.** Some insist that wherever possible the motion pictures should be made in a special laboratory apart from the main production floor. This requires that the regular tools and equipment be moved into the laboratory and the regular operators be brought in from the factory. Studies of the operation can then be made without disturbing regular production in the factory. Although this procedure has many advantages, it is now common practice to take the pictures at the regular work place in the factory. This practice is less costly, aids in securing the cooperation of the workers, and tends to remove some of the mystery of motion and time study. Where the work is of such a nature that the laboratory setup is possible, and where an extended study is warranted, it is not unusual to carry the investi-



gation into the laboratory. Laboratory setups are, nevertheless, exceptions rather than the rule in industry today.

There are other uses for the laboratory which justify its existence, even if not as a place in which to make the pictures. A laboratory is indispensable for storing the motion-picture equipment, for analyzing the film, for constructing the simo charts, and for showing the film to those concerned with improving the methods. The motion study



*Courtesy of General Electric Co.*

FIG. 70. The original motion study laboratory at the Fort Wayne works of the General Electric Co.

laboratory may be used as a classroom by members of the organization interested in learning the micromotion study technique. The laboratory is frequently used as a conference room for foreman and supervisor training programs. Figure 70 shows the motion study laboratory at the Fort Wayne works of the General Electric Company as it appeared in 1929. Figure 71 shows the floor plans of the research laboratory at the University of Iowa. The Armstrong Cork Company Industrial Engineering Center is shown in Fig. 283 on page 462.

**Motion-Picture Film.** Professional motion pictures are made on negative film. This film is developed and, from it, positive prints are made for use in theater projectors. With the development of the amateur camera and 16-mm. film, a reversal process was perfected. The amateur 16-mm. reversal film now most commonly used is coated with a photographic emulsion which permits the film to be exposed



in the camera in the usual way. It is then sent to the manufacturer who processes it in such a way as to produce a positive directly on the original film base. Thus the user receives his original roll of film from the processing station as a positive and ready for projection on the screen. Duplicates of the original 16-mm. film may be obtained when desired.

Supersensitive panchromatic film is most commonly used for motion study work although colored motion pictures also are finding some use in this field. All amateur motion-picture film is made from an acetate base, is non-inflammable, and is known as "safety" film.

**Indexing and Storing Film.** If motion pictures are used extensively, adequate provision should be made for indexing the film and caring for it. One method that has been found successful is to assign a number to each picture and place a small card bearing this number in the picture at the time the film is exposed.

A motion-picture data sheet similar to that shown in Fig. 75 is filled out at the time the picture is made, and this sheet is kept as a permanent record. The roll of film or the film loop is then placed in a box, properly labeled, and filed by number in drawers in a metal filing cabinet. The film may be cross indexed as to kind of operation (i.e., drilling, spray painting, inspection, etc.) and also as to department, kind of product, or in any other way that seems desirable.

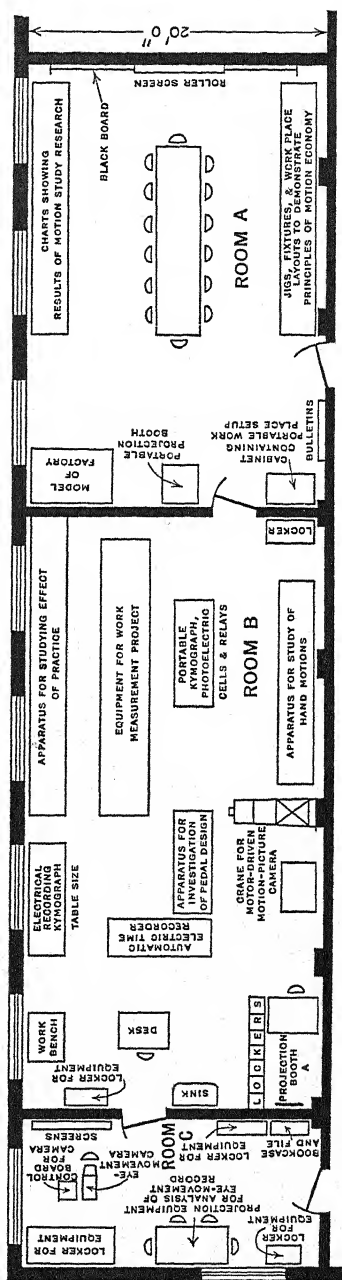


Fig. 71. Floor plan of Iowa Industrial Engineering Laboratory—motion and time study research section.



**Motion-Picture Projector.** The motion-picture projector is indispensable for analyzing film as it must be studied frame by frame in minute detail. Frequently the motions of several members of the body, such as the fingers, arms, and feet, must be studied. This study requires that the same film be analyzed a number of times, once for each member of the body studied.

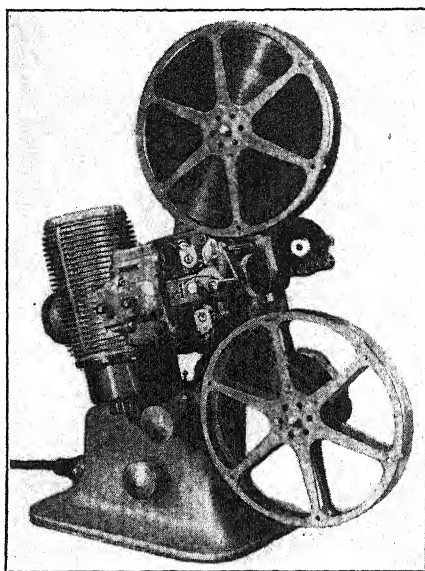


Fig. 72. Motion picture projector (16-mm.) designed for general motion and time study work. The hand crank *A* may be used for film analysis.

The most suitable projector for this purpose is a small one of light weight so that it can be moved around easily on the desk or table. The projector should have a low-powered bulb so that the heat developed by it will not buckle or warp the film when it remains stationary in front of the lens for a long period of time. The projector may be fitted with a lens of short focal length (one inch) so that a relatively large picture can be projected on a screen placed near the projector. The projector should have a hand crank geared to it so that one turn of this crank advances the film one frame in front of the lens for film analysis. (Such as crank *A* in Fig. 72.) By giving this crank a quick turn the frame of film is pulled down in front of the projection lens so quickly that the movement of the subject may be noted on the screen. This aids in finding the points where motions begin, end, or where change of direction occurs. This projector is also equipped with a



mechanical counter which counts the frames passing by the lens. This counter is especially useful when analyzing film made with a constant-speed motor-driven camera. The projector shown in Fig. 73 is controlled by the switches on box A. This control box makes it possible to operate the projector from a distance.

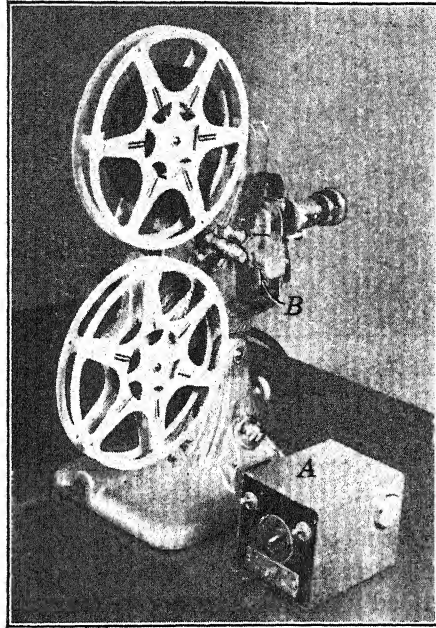


FIG. 73. Motion-picture projector (16-mm.) adapted for film analysis. The special control box A makes it possible to operate this projector from a distance. The frame counter B permits the analysis of films made with an electric motor-driven camera.<sup>4</sup>

A projector with a high-power bulb is needed when pictures are to be shown to a large group of people. If this projector (see Fig. 286 on page 474) is fitted with a tachometer and a variable speed motor, it can be used to show pictures made with a constant-speed camera to advantage. The pictures may be shown at the exact speed at which the operator was working when the pictures were made or at faster or slower speeds of known value.<sup>5</sup>

<sup>4</sup> For detailed description of this projector, see D. B. Porter and L. P. Granath, "How to Convert Projectors for Motion Study," *Factory Management and Maintenance*, Vol. 97, No. 7, pp. 49-50.

<sup>5</sup> See page 360 for a discussion of the use of motion pictures for performance rating of operators.



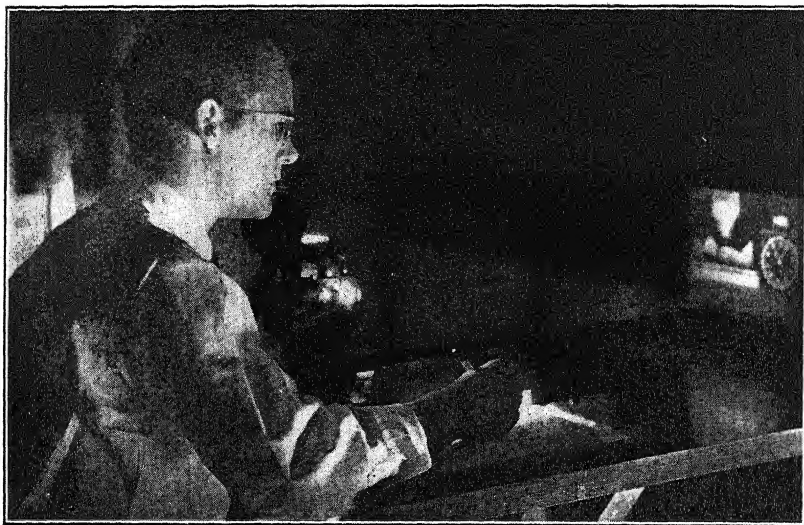


FIG. 74. Projection booth for film analysis.

**List of Equipment for Motion Study Work.** To summarize, the following equipment is recommended where a fairly extensive program is to be carried on:

1. One motion-picture camera, preferably with f.1.9 lens, adjustable focus from 4 feet to infinity, and film capacity of 100 feet.
2. One metal tripod with tilting and panoraming head.
3. One exposure meter.
4. Three or four photoflood lamps (No. 4 size) with reflectors.
5. Two tripods for photoflood lamp reflectors.
6. One microchronometer.
7. One motion-picture projector with low-power bulb and hand crank for film analysis.
8. One motion-picture projector with high-power bulb for showing pictures to large audiences.
9. One portable screen.
10. Suitable cabinets for storage of film.
11. One titling outfit.
12. One rewind, editor, and film splicer.
13. One steel cabinet for storage of equipment.



## CHAPTER 11

### MAKING THE MOTION PICTURES

Motion pictures can be used for numerous purposes in motion and time study work. They are frequently made for: (1) micromotion study, (2) for training factory operators, (3) to show the current method of doing a particular job,<sup>1</sup> and (4) for performance rating in time study work.

Since films for micromotion study are perhaps the most difficult to make, an explanation is given here of the procedure to be followed in making such pictures.

It will be assumed that a particular operation to be studied has been selected from the process chart and that an operation chart of the hand motions required for the performance of this operation has been constructed. It will be further assumed that the analyst has applied the principles of motion economy to the operation without finding an improved method that is entirely satisfactory. This being done, and having made certain that the operation is such as to justify a complete micromotion study of it, the analyst proceeds to make the study.

**Operator to Be Studied.** The first step is to select one or more operators as subjects for making the motion picture. It is of greatest value to make the pictures of those operators who are the most highly skilled and who perform the work in the most satisfactory manner. Every operator who gives promise of contributing something to the establishment of the improved method should be studied. It is often desirable from a psychological standpoint to make motion pictures of every one performing the operation. It is unlikely that information of much value will be obtained from the inexperienced workers; consequently only a few feet of film need be made of these. Occasionally it has been found that the "lazy worker" may be using better methods than some of the more energetic operators. This, of course, is true be-

<sup>1</sup> This third use may be supplemented by a picture taken after an improvement in method has been worked out. Such pictures are sometimes referred to as "before" and "after" films.



cause he attempts to get his work done with the least expenditure of energy.

It is very important and necessary that the workers and the supervisor are told just what is going to be done. Their cooperation should be sought from the very beginning. It is seldom difficult to obtain. In most cases the workers will give their very best performance while the motion pictures are being made, since they know that a permanent record is being made of their work by the motion-picture camera, and that their fellow workers as well as the executives may review their work on the screen.

Since it is not the method used by the average worker but the very best method that is required by motion study, it is essential that the very best operators, those most proficient in performing their work, be studied in determining the proper method for doing the work.

It should be emphasized that motion study makes no effort to force the worker to "move faster" but studies his motions to find the shortest and best ones to use. Motion study aids in finding the easiest and least fatiguing way of doing the work. If the best operators obtainable are used as subjects for the study, the analyst is likely to progress more rapidly on the solution of his problem than if he uses the inexperienced workers. The motions that the operators use are the things being studied and not the speed that they exhibit.

As stated at the beginning of Chapter 1 of this book, motion and time study has several objectives. It is the purpose of stop-watch time study, for example, to determine a time value in minutes or hours which permits the qualified operator to work day after day and week after week without harm or undue fatigue to himself, always being able to perform the task in this standard or specified time. However, in making a micromotion study it is expected that the superior workers who act as subjects for these studies may perform at a faster speed than the "standard" calls for. No one can object to this, for in motion study the discovery of the very best possible *way* of doing the work is the first and foremost object. Those operators who will aid most in determining this method are the ones who should be studied.

**Placing the Camera.** Assuming that the operator or operators to be studied have been selected and understand that a micromotion study is to be made, the motion study analyst is ready to set up his equipment and make the picture.

Although it is not necessary to have pictures of a quality equal to that of professional movies, it is essential that the pictures should be



sufficiently clear when projected to give all necessary details. They should be sharply focused and they should be taken from such an angle as to give a satisfactory picture of all motions of the operator.

The camera should be placed as close to the subject as possible without omitting anything necessary from the picture. Both the work place and the actions of the operator should be considered in positioning the camera. The motions of the operator may occur in two directions—those made perpendicular to the line of sight and those made parallel to the line of sight. The camera should be placed at such an angle, relative to the operator and the work place, that a majority of the motions will be perpendicular to the line of sight. Not only does such an arrangement tend to permit a sharp focus throughout the cycle but it also makes the analysis of the film easier. It is less difficult to judge the nature and extent of movements made at right angles to the line of sight than it is to judge movements made toward or away from the line of sight. The view finder on most motion-picture cameras is sufficiently accurate even at close range to show what will be included in the picture.

The camera should preferably be placed to include the entire range of the worker's motions for the cycle. Seldom is it desirable to follow the movements of the operator by moving the camera as the cycle progresses. It is difficult to anticipate the movements of the operator and almost impossible to keep all his motions in the picture at all times.

In some cases motion pictures may be made profitably from more than one position, although this is by no means required on every operation. It is, however, desirable to make a few pictures of the operator and the work place from a distance in order to have a complete record of the job, and incidentally a good picture of the operator.

It is sometimes advantageous to place a cross-sectioned screen, made with white lines drawn on a black background forming four-inch squares, behind the operator. In certain cases the work bench or the floor may be marked off in a similar manner. This is done to assist in determining the location and the extent of motions when the film is being analyzed. Everything should be done that will assist in making the analysis of the film easy. Such small details as the color of the operator's clothes have an important effect upon the ease with which the motions may be analyzed.

On some occasions Gilbreth used what he called a "penetrating screen" because it gave further assistance in studying and measuring



motions.<sup>2</sup> The penetrating screen resulted from a double exposure of the film. The first exposure was made of a screen of black material marked off into small squares with white lines. This screen was located on the work place at a position where the motions of the operator's hands normally occurred. Having been photographed, the screen was removed, the film was rewound in the darkroom on the original reel, and then the motion picture of the operator was made in the usual way. After the film was processed and projected, the operator appeared to be working with this transparent cross-sectioned screen across the work place.

The camera should be mounted on a tripod, and the tripod should be placed securely on the floor or on top of a solid table or bench so that the camera will be free from vibration while it is in operation.

**Lighting.** Daylight is preferable to artificial light for making pictures; however, indoors it is usually necessary to supplement daylight with some artificial light. Photoflood lamps with suitable reflectors usually supply this additional illumination. These lamps should be located to light properly the darkest places in the picture. It is better to have too much illumination on the subject and stop the diaphragm opening of the camera down than it is to have too little illumination and get a dark picture.

In placing the lighting units it should be remembered that the intensity of illumination from the lamp falling on an object varies inversely as the square of the distance between the source and the object. If the lamp that is ten feet from the object is moved up to a distance of five feet, the intensity of illumination on the object is increased four times. The surest way to know whether the object is sufficiently illuminated is by means of an exposure meter.

**Making the Motion Picture.** If a microchronometer is used, it should be placed so that its entire face will appear in the picture and yet not hide any of the motions of the operator or any part of the work place that should be included in the picture. Neither should motions of the operator interfere with the clock's being in full view at all times. The microchronometer should be placed in focus if it is to be easily read when photographed.

The camera is loaded with film, the film-footage meter set to zero, and the diaphragm opening adjusted for the lighting conditions present and for the speed at which the camera is to operate, if different

<sup>2</sup> F. B. and L. M. Gilbreth, "Applied Motion Study," p. 86, Sturgis & Walton Co., New York, 1917.



from normal. The distance from the center of action of the operator to the lens of the camera should be carefully measured with a tape measure (estimating distance is not satisfactory) and the camera focused accurately. This is particularly important when the camera is placed near the work to be photographed.

Often a card bearing such information as operation name, part number, date of study, department number, and film number is placed in front of the camera and photographed on the first few frames of film. This information identifies the film. Another method is to use but a single number or symbol, which is placed in the picture during the entire "run." A different number is used for each setup or run. This number is referred to as the "film number." A special motion-picture data sheet bearing the film number such as the one shown in Fig. 75 is used to list all data pertaining to the particular study. This sheet, then, forms a permanent record of the information about the work being filmed, as well as of data pertaining to the mechanics of making the picture. Since the same symbol appears on each frame of the film in a given run, it is always possible to refer to the data sheet in order to identify any piece of film.

The analyst should estimate or measure with a watch the time required for a cycle if he has not already obtained this information from previous time standards or from the production department. There should be plenty of material ahead of the operator and everything should be in readiness so that there will be no unnecessary interruptions while the pictures are being made. The operator should be allowed to work some time after the lights are turned on before the camera is set in motion. Some operators require time to become accustomed to the new surroundings and to work off nervousness. Most workers present no serious problem on this last score.

The film is then exposed, making pictures of as many cycles of the operation as desired. It is impossible to give rules as to the number of cycles of an operation to be photographed. It depends upon the circumstances surrounding each case, but a sufficient number of cycles should be taken to give a representative record of the job. It is better to have made too many pictures of an operation than too few.

### **Outline of Procedure for Making Motion Pictures**

1. Secure the cooperation of the foreman and the operators before attempting to make the motion picture. Explain why the picture is being made.







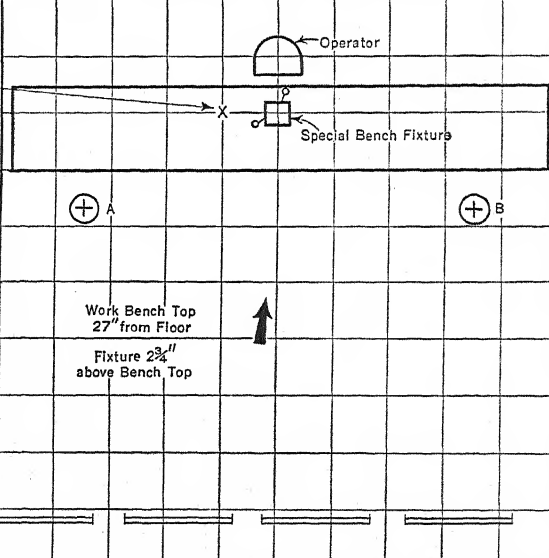
MOTION - PICTURE DATA SHEET									
PLACE L. C. Smith & Corona Typewriters, Inc. Groton, N.Y.						FILM NO. C1			
OPERATION Form Links						OP. NO. 15			
PART NAME Link for Portable Typewriter						PART NO. 357			
MACHINE NAME Special Bench Fixture			MACHINE NUMBER No. 1364			DEPT. No. 9			
OPERATOR NAME & NO. M. S. Fost A1						DATE 7-15-31			
EXPERIENCE An average operator, often on other work						MATERIAL M. S. wire cut to length			
BEGIN 11:00 AM		FINISH 11:50 AM		ELAPSED		UNITS FINISHED		RATING	
CAMERA MAKE EK Co.		CAMERA SERIAL NO. 03221		CAMERA SPEED IN FRAMES/SEC. 16		LENS f.1.9			
DISTANCE OF CAMERA FROM SUBJECT 4' 2"		FOCUS SETTING 4		EXPOSURE METER READING		DIAPHRAGM OPENING f.4.0			
KIND OF FILM E. K. Pan.		SENSITIVITY RATING		NO. OF SPOTS Two		WATTAGE		A 500 C 500 D	
<div style="display: flex; justify-content: space-between;"> <div style="width: 30%;"> <p>Material was placed on the top of the bench at a distance of 10 inches from the center of the fixture</p> <p>Finished parts were disposed of by dropping on bench top at the left of the operator</p> <div style="margin-top: 20px;">  <p>Link before and after forming</p> </div> <div style="margin-top: 10px;">  SPOT LIGHT           </div> <div style="margin-top: 5px;">  CAMERA           </div> <div style="margin-top: 5px;">  WINDOW           </div> </div> <div style="width: 65%;">  </div> </div>									
<b>TOOLS, JIGS, GAUGES:</b> — Special fixture operated with both the right and the left hands.									
MADE BY									

Fig. 75. Motion-picture data sheet.



2. Determine whether electricity is available for the photoflood lamps, microchronometer, and camera if an electric motor-driven camera is to be used.
3. Locate the camera to give the best picture of the cycle of the operation. Use the view finder to ascertain whether the entire cycle is covered.
4. Locate the photoflood lamps to give adequate intensity of illumination without deep shadows. See that the darkest places are properly lighted.
5. Place the microchronometer so that it will be in the picture, and in focus. See that it does not obscure any part of the operation.
6. Place the card bearing the film number or other identification in the picture, preferably near the microchronometer.
7. Have sufficient film in the camera for the number of cycles to be photographed.
8. Determine the proper diaphragm opening by means of an exposure meter and adjust the diaphragm setting on the camera.
9. Measure the distance of the subject from the camera lens and adjust the focus setting on the camera to correspond.
10. Fill in the motion-picture data sheet.
11. Turn on the lights, start the microchronometer, and make the picture.



## CHAPTER 12

### FILM ANALYSIS

After the motion picture has been made and the film processed, it is placed in the projector and shown on the screen, where it may be examined. Since the film contains an exact record of the activities photographed, a process chart, activity chart, man and machine chart, or an operation chart can be made from the film as well as from the actual activity. If the film is projected at the same speed at which it was made, a stop-watch time study can also be made from the film. In this chapter, however, an explanation will be made of the method of analyzing the film for simo chart construction. Before starting the analysis it is customary for the analyst to run the films through the projector several times in order to familiarize himself completely with the operation. A particular cycle is then selected to be analyzed in detail.

The extent to which the analysis of the movements of the hands, arms, legs, head, and trunk will be made depends largely upon the nature of the work. Most operations selected for micromotion study analysis involve either bench work or short-cycle machine work requiring motions of the hands only. It is usually satisfactory to consider the hand as a unit in making the analysis. That is, it is not necessary to analyze the motions of each finger independently. Occasionally, however, an operation will be studied in which all the body movements take place. When such detailed analysis is required it is entirely possible to adapt the technique to this use although much more time is required for the analysis when all the members of the body must be considered separately.

In the bolt and washer assembly, which is to be an example, the simplest form of analysis will be used, that is, analysis of hand motions. Thus, when the thumb and index finger of the right hand grasp a washer it will be assumed that the right hand grasps the washer, etc.

**Forms for Recording Motion-Analysis Data.** As the film is analyzed the data are transferred to a data sheet, commonly called an analysis sheet. Various forms have been devised for this, and the one used will depend upon the type of the work studied and the extent



to which the analysis is to be carried. The forms in Figs. 76 and 79 are very satisfactory for right-hand and left-hand analysis. The extra column on the form in Fig. 76 provides space for the analysis of a third member of the body, such as the foot in punch-press work, or the knee in knee-controlled sewing machine operation. The analysis sheet in Fig. 77 is used by Macy's Department Store when a complete analysis is made.

**Film Analysis of the Bolt and Washer Assembly.** The enlarged print of one cycle of the film showing the operation, "Assemble Three Washers on Bolt," is reproduced in Fig. 78. The pictures were taken at normal speed of 16 exposures per second, and the microchronometer speed was 20 revolutions per minute. The operation is described in detail on page 194. The enlarged print in Fig. 78 will be analyzed in the same manner as if the analyst had the actual film before him. In that case, however, the task would be easier since he would have the film in a projector where he could greatly enlarge it on the screen.

**Analysis of the Left-Hand Motions.** The motions of the left hand of the operator are usually analyzed first. The film is then run back to the beginning of the cycle and is analyzed for the motions of the right hand.

To begin the analysis, the film is run through the projector until the beginning of a cycle is found. This is usually the point where the hand

[illegible]

Fig. 76. Micromotion study analysis sheet.







the analysis as it shows the two hands at the instant they are beginning to separate. The clock reads 595, meaning  $5^{95}/_{2000}$  of a minute from zero.

The motions of the left hand are recorded on the analysis sheet (see Fig. 79) in the column marked "Description Left Hand." The clock reading is recorded in the first column, 595 being the time at which the motion *transport loaded* begins. The symbol for this motion is placed in the third column and the motion is described "Carries assembly to bin."<sup>1</sup> The film is then examined frame by frame until this therblig (for the left hand) ends. The frame of film showing the left hand in the act of releasing the assembly also shows the clock to read 602. Therefore, 602 is recorded in the second horizontal line and in the first vertical column. Since the operator's left hand is now beginning the therblig *release load*, the symbol for this therblig is placed in the third vertical column and the description of the therblig "Releases assembly" is recorded in the fourth column. The analyst now turns to the film and examines it further, looking for the end of the *release load* and for the beginning of the next motion *transport empty*. The very next frame of film shows the operator's left hand in the act of moving empty to the bin of bolts; consequently the *release load* therblig has ended and the *transport empty* motion has begun. The clock is read 604, and this reading is recorded in the third horizontal line and in the first vertical column. The symbol for *transport empty* is placed in the third column, and the description of the therblig is noted in the fourth column. In a like manner the film is examined through the entire cycle, the analyst noting where one motion ends and the next one begins and recording the data on the analysis sheet. After the analysis has been made for both hands, the clock readings are subtracted to get the elapsed time for each motion. These subtracted times are recorded in the second vertical column.

**Analysis of the Right Hand.** After the motions of the left hand have been analyzed, the film is run back to the starting place and the motions made by the right hand are analyzed and recorded on the right side of the analysis sheet in Fig. 79. Referring to the second frame of film in the upper left-hand corner of Fig. 78, the operator's right hand is beginning the motion *transport empty*, the hand moving to the bin of lock washers. Therefore, the clock reading

<sup>1</sup> It is best practice to let the therblig symbol indicate the action, thus making it unnecessary to include the verb in the description. The description of the first therblig would therefore have been "Assembly to bin" instead of "Carries assembly to bin." The verbs have been included on the analysis sheets and simo charts in this book in order to aid the reader in learning the meanings of the therblig symbols.



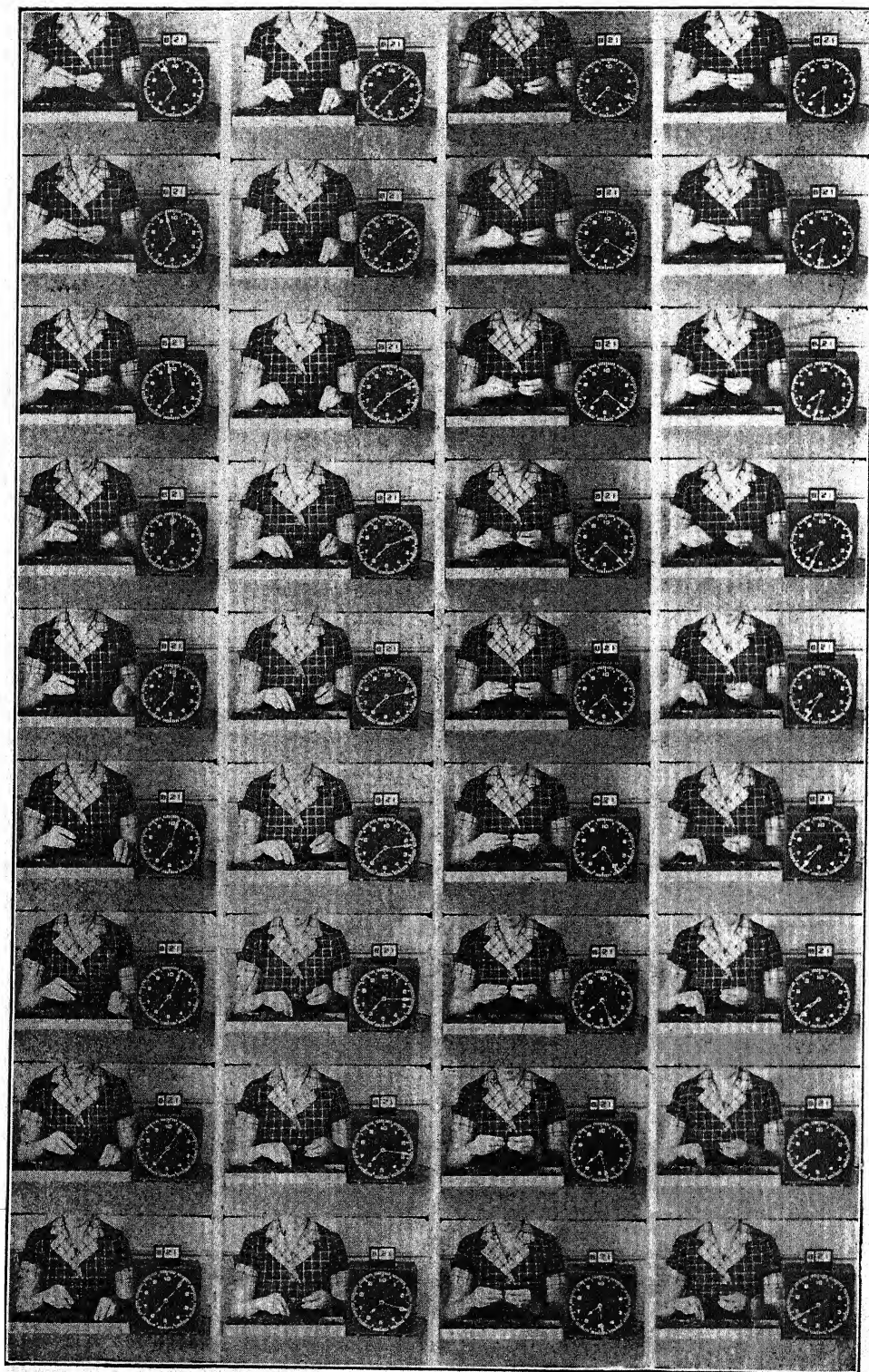
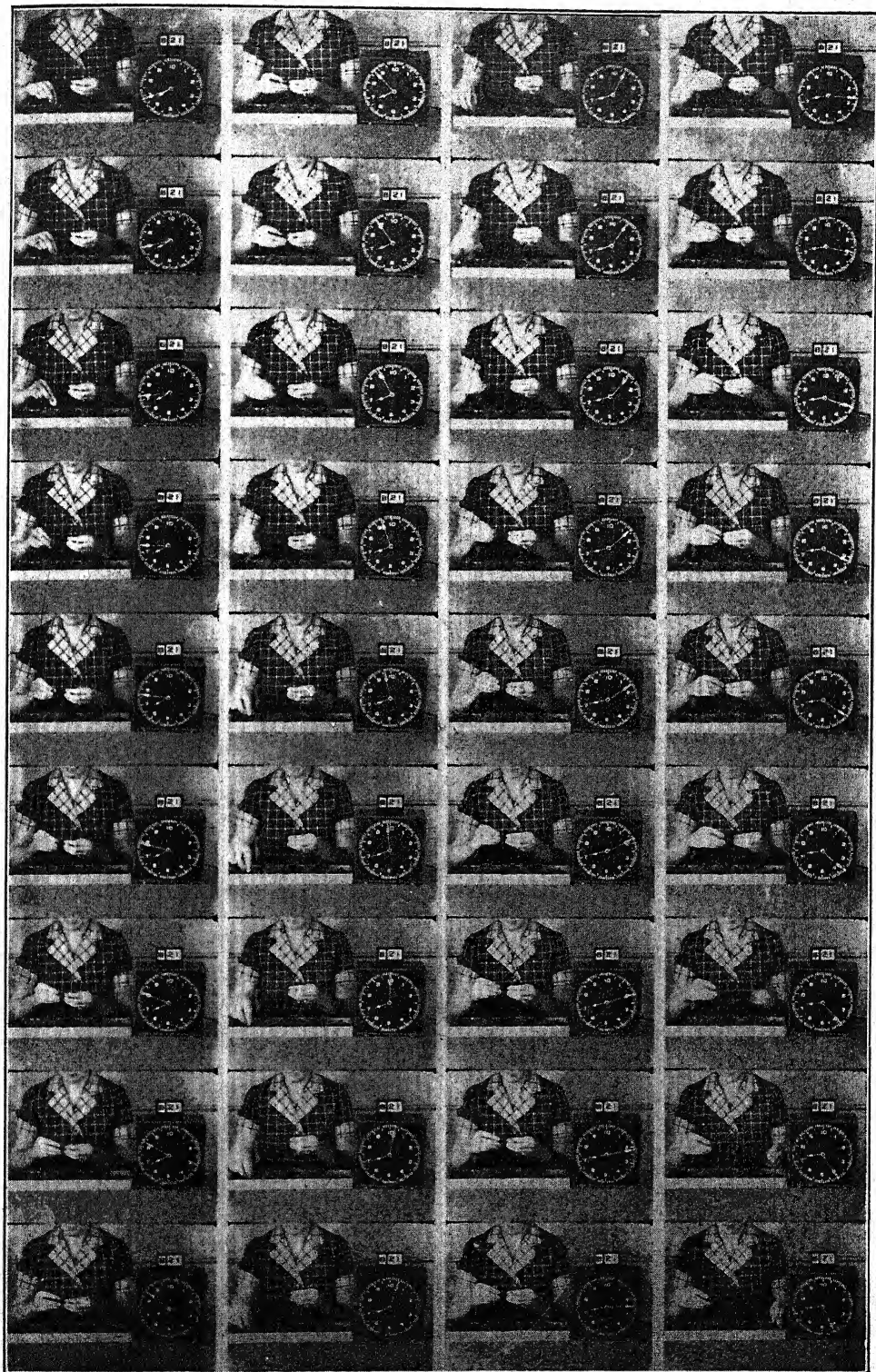


FIG. 78. Print of motion-picture film showing one complete





cycle of the bolt and washer assembly—old method.



595 is recorded in the first vertical column under the heading "Clock Reading" for the right hand in Fig. 79. The therblig symbol for *transport empty* is placed in the third vertical column, and the description of the motion is recorded. The film is then studied frame by frame until the point is found where the motion *transport empty* for the right hand ends and the next one begins. This motion is a

MICROMOTION STUDY ANALYSIS SHEET											
PART Bolt and washer assembly - Old Method						DEPARTMENT AY16			FILM NO. B21		
OPERATION Assemble 3 washers on bolt						OP. NO. A32					
OPERATOR M. Smith 1C634				DATE 1-26-48		ANALYSED BY M.E.R.			SHEET NO. 1 OF 1		
CLOCK READING	SUBTRACTED TIME	THERBLIG SYMBOL	DESCRIPTION LEFT HAND			CLOCK READING	SUBTRACTED TIME	THERBLIG SYMBOL	DESCRIPTION RIGHT HAND		
595	7	TL	Carries assembly to bin			595	26	TE	Reaches for lock washer		
602	2	RL	Releases assembly			621	6	St+G	Selects and grasps washer		
604	4	TE	Reaches for bolt			627	7	TL	Carries washer to bolt		
608	2	St+G	Selects and grasps bolt			634	6	P	Positions washer		
610	17	TL	Carries bolt to working position			640	12	A+RL	Assembles washer onto bolt and releases		
627	5	P	Positions bolt			652	8	TE	Reaches for steel washer		
632	104	H	Holds bolt			660	8	St+G	Selects and grasps washer		
736	7	TL	Carries assembly to bin			668	9	TL	Carries washer to bolt		
743	2	RL	Releases assembly			677	3	P	Positions washer		
745						680	10	A+RL	Assembles steel washer and releases		
						690	6	TE	Reaches for rubber washer		
						696	10	St+G	Selects and grasps rubber washer		
						706	9	TL	Carries washer to bolt		
						715	5	P	Positions washer		
						720	16	A+RL	Assembles washer and releases		
						736					

Fig. 79. Analysis sheet for bolt and washer assembly—old method.

long one because the hand moves very slowly in order to allow time for the left hand to dispose of the assembly and procure a bolt. It is not until the frame in the middle of the second row of pictures of Fig. 78 that the operator begins to *select* and *grasp* a lock washer from the bin on the bench. The clock is read 621, and the data are recorded on the analysis sheet, and so the analysis is continued for the remainder of the cycle. After the analysis has been made for both hands and the subtracted time obtained, it is possible to picture the entire cycle easily and accurately. The left hand is analyzed independently of the right hand except that the cycle must begin and end at approximately the same point for the two hands. It must be remembered that the subtracted time shown in Fig. 79 is in 2000ths of a minute.



As many cycles of the operation may be analyzed as seem necessary. Usually one or two are all that are required if care is used in their selection.

MICROMOTION STUDY  
SIMO CHART

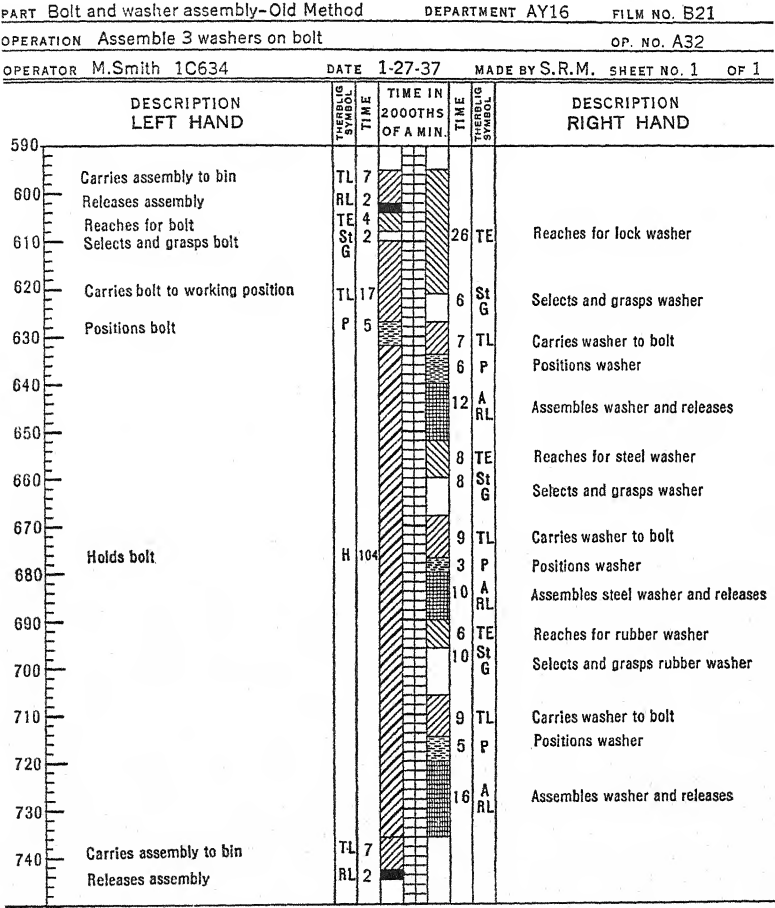


Fig. 80. Simo chart for bolt and washer assembly—old method.

CONSTRUCTION OF SIMULTANEOUS MOTION-CYCLE CHARTS

The time for each therblig recorded on the analysis sheet may be shown to scale by means of a simultaneous motion-cycle chart, commonly called a "simo chart." Either the analysis sheet or the simo



chart may be made independently, or the simo chart may be constructed from the data on the analysis sheet.

When a full simo chart showing every moving member of the body is made, it is customary to use a sheet of cross-section paper 22 inches wide with lines ruled 10 to the inch. For operations longer than one-half minute some analysts use paper with lines ruled 10 to the half inch, or paper ruled in millimeters in order to condense the chart. However, since the divisions are closer together, this paper is more difficult to use than the decimal-inch paper. Headings containing information such as that shown at the top of Fig. 77 are often printed in quantities and are pasted across the top of the cross-section paper.

For many operations, however, it is not necessary to construct a complete chart of all the moving members of the body. A simo chart of the two hands for the bolt and washer assembly is shown in Fig. 80. Exactly the same procedure would be used to construct a chart showing the motions of the arms, legs, head, trunk, and other parts of the body.

The vertical scale shown in the center of the chart in Fig. 80 represents time in 2000ths of a minute. The therblig description, symbol, color, and relative position in the cycle all appear on the chart. The time required for each motion is drawn to scale in the vertical column and colored to represent the particular motion. The sheet is arranged much like the analysis sheet. The clock read 595 at the beginning of the motion *transport loaded* for the left hand; therefore this point is located on the vertical scale by a heavy black horizontal line at the top of the column. The first motion, *transport loaded*, required seven winks ( $\frac{7}{2000}$  of a minute); therefore, seven divisions are marked off on the vertical column for the left hand and a heavy black line is drawn in. The space above this horizontal black line is then colored solidly in green<sup>2</sup> with a pencil, No. 375. The next therblig for the left hand is *release load*, which required two winks. In a similar manner this elapsed time is marked off on the vertical scale immediately below the heavy black line, and another horizontal line is drawn in. The area for this therblig is colored red. And so for the remainder of the cycle the motions are marked off to scale and each area is colored with the standard therblig color. The motions made by the right hand are charted on the right-hand side of the sheet in exactly the same way as those for the left hand.

<sup>2</sup>Since color cannot be reproduced in this book, color symbols are used instead. For standard therblig colors see Fig. 62 on page 96.



## MICROMOTION STUDY

## SIMO CHART

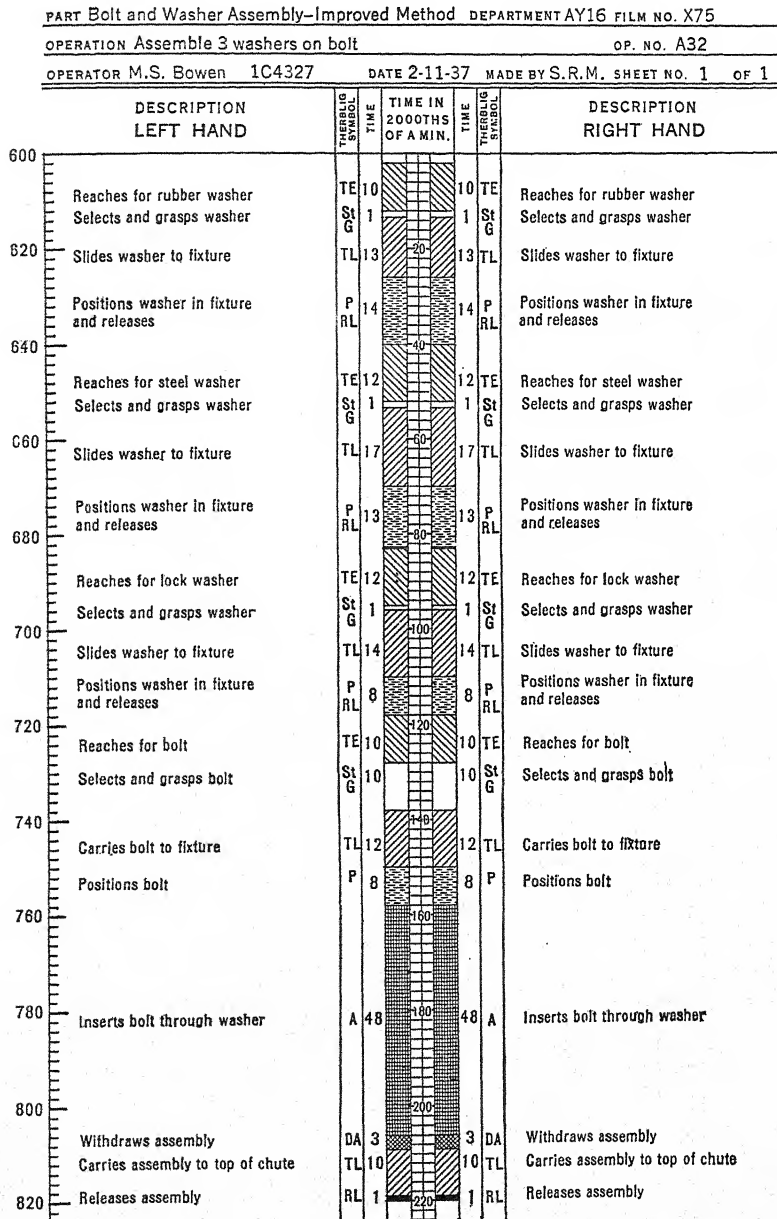


FIG. 81. Simo chart for bolt and washer assembly—improved method.



Figure 81 shows the simo chart for one cycle of the *improved method* of bolt and washer assembly as described on page 195.

**Analysis of the Link-Forming Operation.** The simple operation of bending a "hook" on each end of a short piece of wire to form a link (see Fig. 82) for a portable typewriter was the subject of a number of studies made by the author, and because this operation involves the use of a fixture and because it is short in length it will be used as an example.

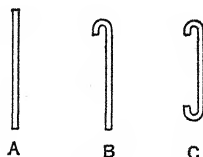


FIG. 82. Link for portable typewriter. A. Soft steel wire; B. Link with one end formed; C. Finished link.

The camera used for making the motion pictures of this operation was driven by a synchronous motor and operated at a constant speed of 1000 exposures per minute. Therefore, no microchronometer was needed, and the time interval from one frame of film to the next was exactly  $\frac{1}{1000}$  of a minute. See Fig. 84.

**Description of the Link-Forming Operation.** The material from which the link was formed consisted of soft steel wire cut from wire stock 0.045 inch in diameter to uniform length of  $1\frac{1}{4}$  inches. The material was supplied to the operator in metal containers, and the operator emptied the stock of cut wire on the linoleum-topped bench at the right of the fixture as she needed it. The link was formed in the following manner.

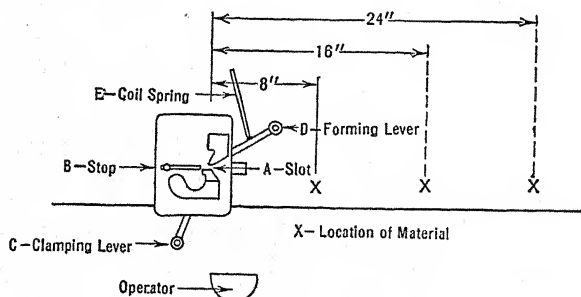


FIG. 83. Fixture and layout of the work place for forming link.

The pictures in Fig. 84 give a reproduction of each element of one complete cycle. The fixture was mounted securely on the bench so that its top surface was  $2\frac{3}{4}$  inches above the top of the bench. The top of the bench was 27 inches above the floor. The material was spread out over the surface of the bench top so that it could be grasped more easily. The operator, seated behind the bench, picked



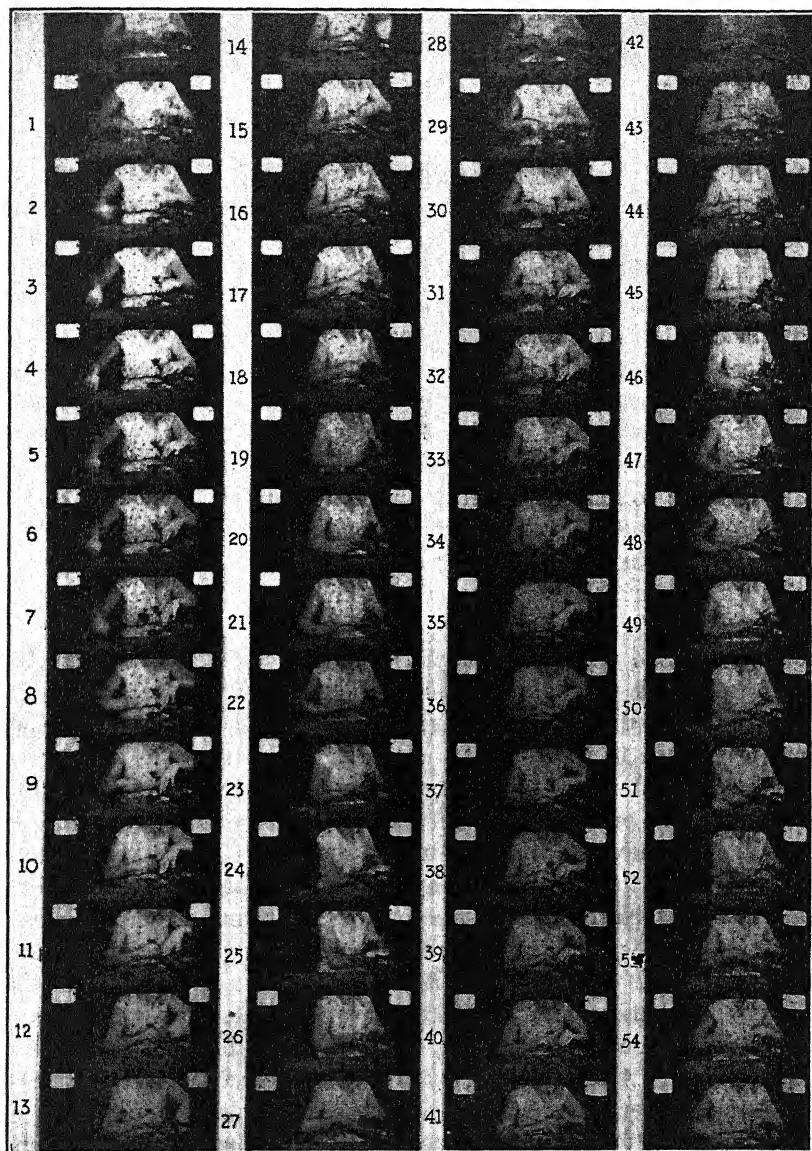


FIG. 84. Print of motion-picture film showing one complete cycle of the link-forming operation.



up one piece of material with the thumb and index finger of her right hand, carried it to the left, and inserted it into the slot *A* in the fixture. See Fig. 83. The operator pressed the piece of material against a stop *B* in the fixture, and at the same time she clamped the piece into place by moving lever *C* to the left with her left hand. Then, with the right hand she grasped the knob of the forming lever *D* which extended to the right of the fixture and was about 3 inches above the top of the bench. The right hand rotated the forming lever in the clockwise direction about the center of the fixture as an axis, through approximately 180 degrees, the radius of rotation being 8 inches. The lever was moved in a plane parallel to the top of the bench. This movement of the lever formed the "hook" on one end of the link. The operator then returned the lever in the counterclockwise direction toward its original position. A coil spring *E*, fastened to the forming lever and to the bench, assisted the operator in returning the lever to its original position. This spring made it possible for the operator to release the forming lever after she had returned it through about one-half its return travel, the spring pulling the lever back the remainder of the distance.

After the operator had released the knob of the lever she moved her hand slightly to her right and into a position about 4 inches in front of her and waited an instant while her left hand removed the half-formed link from the slot in the fixture. Then the two hands together turned the link end for end and placed it back into the slot. Care was taken to insure that the "hook" was turned in the proper direction so that after the link had been completely formed the two hooks would be on the same side. As the right hand held the link in place in the fixture, the left hand moved the lever *C* to the left, clamping the link in the slot as in the first part of the cycle. The right hand then grasped the knob of the forming lever and, as before, moved it through 180 degrees in the clockwise direction forming the second end of the link. While the right hand was forming the end of the link, the left hand continued to hold lever *C* in its position as far to the left as it would go, clamping the link in the fixture while it was being formed. After the link was formed, the right hand returned the forming lever toward its original position, releasing the knob of this lever directly in front of the operator. She then moved her hand to her right to pick up a piece of material from the bench for the beginning of the next cycle. In the meantime the left hand released the knob of lever *C* and reached forward to remove the finished formed link from the slot in the fixture. The left hand then carried the link to the left where it was dropped on top of the bench. During this



## MICROMOTION STUDY

SIMO CHART

PART Link for typewriter		DEPARTMENT 9		FILM NO. C18	
OPERATION Form link for typewriter		DATE 2-15-37		OP. NO. G11	
OPERATOR A.S.Sanders A2		MADE BY S.A.R.		SHEET NO. 1 OF 1	
DESCRIPTION LEFT HAND	TIME IN 1000THS OF A MIN.	TIME IN 1000THS OF A MIN.	DESCRIPTION RIGHT HAND	TIME IN 1000THS OF A MIN.	DESCRIPTION RIGHT HAND
Returns clamping lever and releases it	2				
Moves hand to fixture	3		4	TE	Reaches for material
			2	St G	Selects and grasps one piece
Grasps formed link in fixture	6		6	TL	Carries piece to fixture
Carries formed link to left and releases it	3		6	P RL	Inserts piece in fixture and releases it
Moves to clamping lever and grasps knob	3		2	TE G	Reaches for forming lever and grasps knob
Moves lever to extreme left	3		5	U	Forms 1st end of link
Holds lever in this position	6		3	TL RL	Returns forming lever and releases it
Returns lever to original position and releases it	3		4	TE UD	Moves hand toward fixture and waits for left hand
Moves hand to fixture	3		4	TE	Moves hand to fixture
Grasps piece, turns it end for end in fixture and releases it	8		8	P	Assists left hand in turning piece end for end in fixture
Moves to clamping lever and grasps knob	3		2	TE G	Reaches for forming lever and grasps knob
Moves lever to extreme left	3		5	U	Forms 2nd end of link
Holds lever in this position	8		3	TL RL	Returns forming lever and releases it
Returns clamping lever and releases it					

FIG. 85. Simo chart of link-forming operation.



time the operator was looking to her right where the right hand was grasping a piece of material from the top of the bench for the next cycle.

Figure 85 shows the simo chart for the link-forming operation.

**Complete Analysis of Hand Motions.** Confusion sometimes occurs when making a left- and right-hand motion analysis because some members of the arm are performing certain motions while other members are performing other motions. The first motion on the simo chart in Fig. 86, for example, shows the thumb, first, and second fingers of the right hand performing a grasp while the palm, third, and fourth fingers of the same hand are holding the bone. The operation is folding and creasing sheets of paper by the improved method described on page 221. The right hand carries the bone at all times, although it is used only during a small part of the cycle.

When a complete analysis of an operation is made each member of the arm is analyzed separately, i.e., the upper arm, lower arm, wrist, first finger, second finger, etc. The film is run back to the starting place after the analysis of each member, and a separate vertical column on the simo chart is required for recording the motions of each. Although Fig. 86 does not show the movements of the head, trunk, and legs it does show all motions of the arms, hands, and fingers.

Had a simple left- and right-hand simo chart been made of the paper-folding operation it would have shown those therbligs performed by the thumb, first, and second fingers only. A note would have been included on the chart to show that the bone was carried in the right hand throughout the entire cycle.

**Using the Simo Chart.** After the simo chart of the operation has been made, the task of finding a better way of doing the work has just begun. A thorough study of the chart is ordinarily the first step in this task.

The simo chart aids one in grasping a picture of the complete cycle in all of its details and assists in working out better combinations of the most desirable motions. The simo chart of Fig. 80 shows in a very clear way that the left hand is used during most of the cycle for holding the bolt. This at once suggests that some mechanical device be used which will permit the left hand as well as the right to do more useful work.

It is often found that the sequence of motions in one kind of work may be used in other kinds of work, or a particularly good sequence in one operation may suggest a more efficient sequence in



another operation. The simo chart shows very distinctly where delays occur in the cycle, and it aids in finding an effective way of eliminating the delays.

## MICROMOTION STUDY

## SIMO CHART

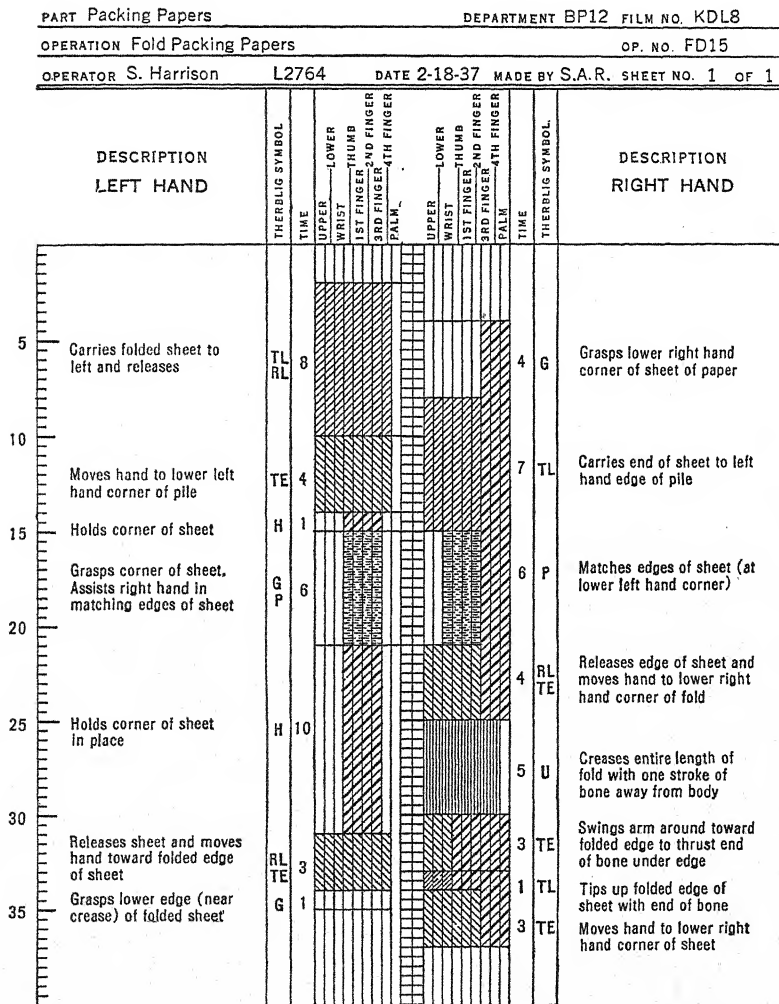


FIG. 86. Simo chart of folding paper.

The next five chapters give some methods of attack that may be useful in this problem of improving the method of doing a given task.



**Possibility Charts.** After the suggestions for the improvement of the method have been secured and when worthwhile changes seem practicable, a possibility chart may be constructed. This is a simultaneous motion-cycle chart showing the proposed method. A competent analyst will be able to draw up such a chart listing the necessary motions in order and indicating the time for each. Such possibility charts can be made with a surprising degree of accuracy by one trained in the micromotion study technique and experienced in making such charts.

**Modified Simo Chart.** Some organizations find it satisfactory to list the motions and the motion times on the simo chart, plotting the motion time values on a graduated scale as shown in Figs. 89 and 90. The colored therblig identifications are not used. Moreover, such charts may be prepared with a typewriter using hectograph carbon paper on forms printed with hectograph ink. With such a master, a number of copies can be made. The simo charts for one operation in the process of packing

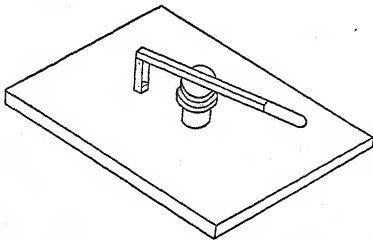


FIG. 87. Fixture used for pressing cheese in cup by the old method.

Cheddar cheese in paper cups shown in Figs. 89 and 90 were made in this manner.

In this case the company had several branch plants packing cheese, and the charts together with films of the original method and of the improved method were sent to each plant so that the plants could benefit from this work.

The original method of "Crimp Foil Liner over Top, Press Cheese in Cup, Code Date, and Move to Wrapper" was as follows. The operator, standing at a table, picked up a cup from the table at her extreme left, placed it on the table directly in front of her, folded the tinfoil liner down on the cheese, placed it in a hand fixture as shown in Fig. 87, and lowered the lever which pressed the cheese down in the cup. Then the cup was removed from the fixture, an insert and a cover placed on top of the cup, and the cover pressed down. The cup was then turned over and a code date stamped on the bottom, using a hand stamp and an ink pad.

In investigating operations that seem to lend themselves to the use of duplicate fixtures it is often desirable to plot on the simo chart the motions used in producing two units, as it is easier to



compare the old with the improved method. This was done in Fig. 89.

Having this new fixture in mind, the engineer drew heavy solid vertical lines beside the motions that he thought could be eliminated entirely, and heavy dotted vertical lines beside the motions that he thought probably could be reduced in time. This procedure gives a fairly definite idea of the potential savings that can be expected after the proposed fixture has been built and put into use.

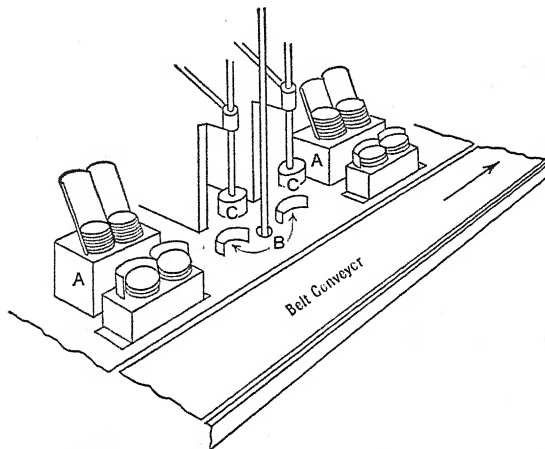


Fig. 88. Fixture used for pressing cheese in cups by the improved method. A. Supply of tinfoil liners, covers, etc.; B. Nests for positioning cups under plungers; C. Plungers (operated by foot) for pressing cheese into cups.

The improved method, after it was worked out and put into effect in the factory, was filmed and a simo chart made of it (see Figs. 88 and 90). The improved method consisted of picking up two cups filled with cheese from a conveyor belt and placing them on the front edge of the table. The two hands then folded the tinfoil liner down on the first cup and placed it into a nest in the fixture. The foil was then folded down on the second cup and it was placed into the other nest in the fixture. The two hands held the two cups while the foot operated the two plungers which came down vertically, pressing the cheese into the cups. The operator then grasped an insert and then a cover in each hand and placed them on the cups. The cups were removed a few inches from the fixtures, the covers pressed into place, and the cups turned over and the code date stamped on the bottom of each cup.



## FILM ANALYSIS

## MICROMOTION STUDY

SIMO CHART

PART: ½ lb. and 1 lb. Cheddar Cheese			FILM NO.: S1486
OPERATION: Crimp Foil Liner over Top, Press Cheese in Cup,			OP. NO.:
Code Date, Move to Wrapper			DATE: 12-18-47
OPERATOR: M. Sanderson		MADE BY: M.G.S.	SHEET NO.: 1 of 1
NO. UNITS PER CYCLE: 2-Cup Cycle		ORIGINAL METHOD: X	IMPROVED METHOD:
FOOT	LEFT HAND	100THS OF A MINUTE	RIGHT HAND
	T.E. to cup and aid right hand	10	10 T.E. to cup and move to position
	Crimp foil liner over cheese	28	26 Crimp foil liner over cheese
		25	
	Aid right hand	5	7 Aside cup
	T.E. to cup and grasp	8	17 Hold lever up
	Place cup in position to press	15	
	Hold cup	11	17 Lower lever pressing cheese to cup, raise
	Aside cup to table	7	7 Hold lever up
	T.E. pick up inserts, hold while right hand places, aside (6 at a time)	18	18 T.E. to instruction inserts in left hand, grasp and place on top of cheese in cup
		100	
	Aid place cover	13	32 Place cover and T.E. for next cover
	Shove cup aside	5	
	Move next cup in position	14	125
	Turn cups upside down (1 in each hand)	10	10 Same as left
	T.E. for stamp pad, hold while right stamps, aside pad	13	13 T.E. for stamp-stamp cover-aside stamp-avg. 12 per time
	Shove to wrapper (1 each hand)	5	5 Same as left
	T.E. to cup and aid right hand	10	10 T.E. to cup and move to position
	Crimp foil liner over cheese	28	26 Crimp foil liner over cheese
		175	
	Aid right hand	5	7 T.L. and R.L. cup
	T.E. to cup and grasp	8	17 Hold lever up
	T.L. cup in position to press	15	
	Hold cup	11	17 Lower lever pressing cheese in cup, raise
	T.L. cup to table	7	7 Hold lever up
	T.E. pick up inserts, hold while right hand places, aside (6 at a time)	18	18 T.E. to instruction inserts in left hand, grasp and place on top of cheese in cup
	Aid place cover	13	32 Place cover and T.E. for next cover
	Shove cup aside	5	
	Move next cup in position	14	275
	Turn cups upside down (1 in each hand)	10	300
	Reach for stamp pad, hold while right stamps, aside pad	13	13 T.E. for stamp-stamp cover-aside stamp-avg. 12 per time
	Shove to wrapper (1 each hand)	5	5 Same as left
	NOTE: In order to compare Old and New Methods a one-cup cycle of Old Method has been shown twice.	324	Indicates that element probably could be completely eliminated. ----- Indicates element probably could be reduced.

Fig. 89. Modified simo chart of one operation in the process of packing Cheddar cheese in paper cups by the old method. Size of chart 8½ × 17 inches.



## MICROMOTION STUDY

## SIMO CHART

PART: $\frac{1}{2}$ lb. and 1 lb. Cheddar Cheese		FILM NO.: S1347
OPERATION: Crimp Foil Liner over Top, Press Cheese in Cup, Code Date, Move to Wrapper		OP. NO.: c-27
OPERATOR: M. Sanderson		DATE: 1-12-48
MADE BY: M.G.S.		SHEET NO. 1 OF 1
NO. UNITS PER CYCLE: 2 Cup Cycle	ORIGINAL METHOD:	IMPROVED METHOD: X

FOOT	LEFT HAND	100THS OF A MINUTE	RIGHT HAND
	T.E. and G. cup	7	8 T.E. and G. cup
	T.L. and R.L. cup	9	10 T.L. and R.L. cup
	Fold over tinfoil liner on first cup	28	25
			26 Aid left hand to fold over tinfoil liner on first cup
	R.L. and T.E.	6	50
	G. and T.L. to position	6	6
			6 T.E. to next cup
	Fold over tinfoil liner on second cup	28	28
			28 Aid left hand to fold over tinfoil liner on second cup
		75	
	Grasp cup	5	4
	Slide into position to press	9	10
			10 Idle
	Hold while press	7	100
	T.E. to insert	4	7
			7 Hold while press
	Grasp insert	22	5
			5 Idle
			7 T.E. to insert
		125	14
			14 Grasp insert
	T.L. to cover	5	8
	Position insert and G. cover	7	8
			8 T.L. to cover
	T.L. to cup	10	8
			8 Position insert and G. cover
	Position	6	150
	Slide out $3\frac{1}{2}$ "-4"	4	6
	Press cover down	4	6
	Grasp	4	4
			4 Slide out $3\frac{1}{2}$ "-4"
			4 Press cover down
			4 Grasp
	Turn over and R.L.	11	175
			11 Turn over and R.L.
	Idle	29	1
			1 T.E. to stamp
			5
			5 G. and T.L. stamp to cup
			13
			13 Stamp 2 cups
		200	
		210	8
			8 T.L. and R.L. stamp
		225	
		250	
		275	
		300	
		324	
			Net reduction 35%
			Last 40 frames of this operation could be eliminated by stamping from bottom at the time of pressing.

FIG. 90. Modified simo chart of one operation in the process of packing Cheddar cheese in paper cups by the improved method. Size of chart  $8\frac{1}{2} \times 17$  inches.



The two simo charts when placed side by side make it easy to visualize the changes that were made in the method. Originally it required 0.324 minute for two cups, whereas by the improved method it requires but 0.210 minute for two cups, a reduction in time of 35 per cent.



## CHAPTER 13

### THE USE OF THE FUNDAMENTAL HAND MOTIONS

Although the definition of each therblig has been given in a preceding chapter, further explanation is needed in certain cases. Also, since each motion requires, for its performance, time and energy on the part of the worker, the elimination of motions, or the better arrangement of such as are indispensable, constitutes part of the regular technique of improving methods of work. Information that will aid in making better use of the therbligs is included in this chapter, and a check list follows the discussion of each therblig.

**Select.** The time for select is frequently so short in duration that it is impossible to measure it with the camera at ordinary speeds. When this is the case it is advisable to combine it with either the preceding or the following motion. Since select usually precedes grasp, it is good practice to combine these two. The symbols for both motions should be included on the analysis sheet, and the color for the most important or the predominating motion should be used in making the simo chart. Usually it will be the motion other than select.

Color can be seen more quickly than shape; therefore color should be used to aid in selecting or sorting whenever possible. For example, in sorting photographic snapshot prints into batches after the printing, developing, and drying operations, it was found desirable to use inks of different colors for stamping identification numbers on the back of the paper before printing. Sorting these prints by color of the ink is much easier and faster than sorting by key letters or figures.

Also, painting a tool the same color as the place where it is to be kept in the drawer saves time when putting it away and finding it the next time.<sup>1</sup>

#### Check List for Select

1. Is the layout such as to eliminate searching for articles?
2. Can tools and materials be standardized?
3. Are parts and materials properly labeled?

<sup>1</sup> F. B. Gilbreth, "Motion Study," p. 47, D. Van Nostrand Co., New York, 1911.



4. Can better arrangements be made to facilitate or eliminate select—such as a bin with a long lip, a tray that pre-positions parts, and a transparent container?
5. Are common parts interchangeable?
6. Are parts and materials mixed?
7. Is the lighting satisfactory?
8. Can parts be pre-positioned during preceding operation?
9. Can color be used to facilitate selecting parts?

**Grasp.** There are two main types of grasp: (1) *pressure grasp* as in grasping a pencil lying flat on a table top; and (2) *full-hook grasp* as in grasping a pencil lying on a table top with one end raised an inch or so, so that the thumb and fingers are able to grasp by reaching around it (hook) instead of grasping by pinching.<sup>2</sup>

An investigation<sup>3</sup> of grasping small pieces of wire used in making a link for a portable typewriter (see page 138) showed that it required twice as long to grasp a piece using a pressure grasp as it did using a full-hook grasp. A summary of these data is given in Table IV. The same investigation revealed that the time for the

TABLE IV  
TIME REQUIRED FOR A PRESSURE GRASP VS. A HOOK GRASP  
Link for Portable Typewriter  
Time in Minutes

Study No.	Position of Material	Time Required to Grasp			
		Av.	Mode	Min.	Max.
X51	At random on table top (pressure grasp)	0.00558	0.0050	0.0035	0.0110
X53	Horizontal in grooves (hook grasp)	0.00225	0.0020	0.0020	0.0030

<sup>2</sup> For a classification of "get" see Fig. 276 on page 446.

<sup>3</sup> Ralph M. Barnes, "An Investigation of Some Hand Motions Used in Factory Work," *University of Iowa Studies in Engineering Bulletin* 6, p. 29, 1936.

For results of other motion study investigations conducted in the University of Iowa Industrial Engineering Laboratory, see Ralph M. Barnes and M. E. Mundel, "Studies of Hand Motions and Rhythm Appearing in Factory Work," *Bulletin* 12, 1938; "A Study of Hand Motions Used in Small Assembly Work," *Bulletin* 16, 1939; "A Study of Simultaneous Symmetrical Hand Motions," *Bulletin* 17, 1939; and Ralph M. Barnes, M. E. Mundel, and John M. MacKenzie, "Studies of One- and Two-Handed Work," *Bulletin* 21, 1940.



grasp was not greatly affected by the distance through which the hand moved in either the motion preceding or the one following the grasp, other conditions being constant.

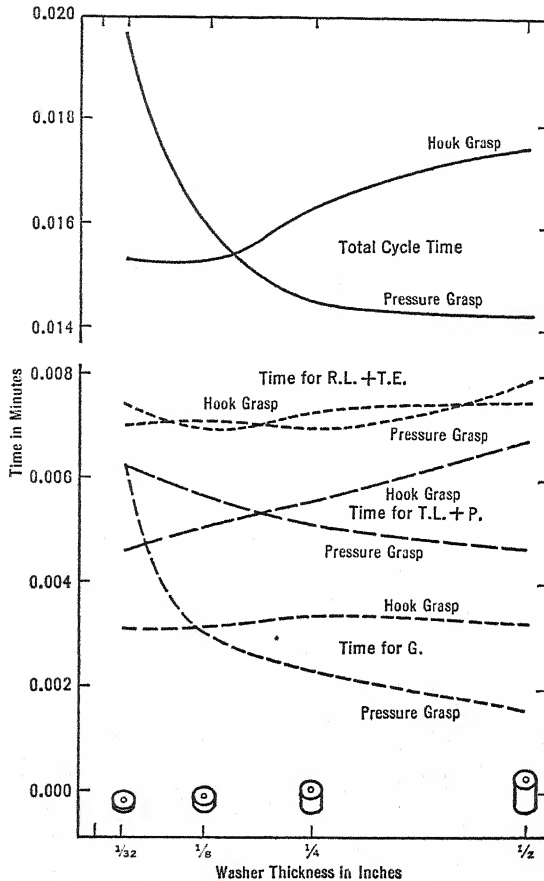


FIG. 91. Curves showing results of study of time required to grasp washers from a flat surface using a hook grasp and a pressure grasp. Four different thicknesses of washers were used. Averages of median time values for five male and five female operators are shown.

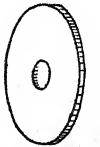
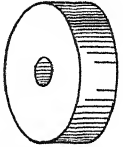
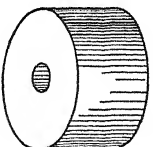
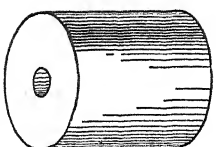

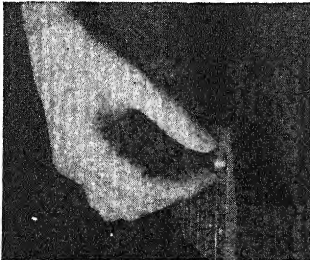
The results of a study<sup>4</sup> of the time required to grasp washers from a flat surface using a hook grasp and a pressure (pinch) grasp are given in Fig. 91 and Table V.

The operator merely picked up a washer from one flat surface, carried it through a distance of 5 inches, and disposed of it onto

<sup>4</sup>University of Iowa Studies in Engineering, *Bulletin* 16, p. 10.



TABLE V  
TIME REQUIRED TO GRASP, CARRY, AND DISPOSE OF WASHERS FROM A FLAT SURFACE, USING A "HOOK" GRASP AND A "PRESSURE" GRASP

					Time in Minutes	GRASP
	Hook	Pressure	Hook	Pressure		
 Pick up washer from "Grasp" grid shown above.	0.00315	0.00629	0.00314	0.00308		Time in Per Cent (Shortest Time = 100%)
	101	397	100	195		
 TRANSPORT LOADED AND POSITION Carry washer through distance of 5 inches and position on "Release" grid.	0.00465	0.00628	0.00510	0.00571		Time in Minutes
	100	132	110	121		
TOTAL CYCLE (G. + T. L. + P. + R. L. + T. E.)	0.01527	0.01960	0.01524	0.01590		Time in Per Cent (Shortest Time = 100%)
	100	138	100	112		
			0.01630	0.01450		
			121	108		
			0.00561	0.00514		
			109	147		
			0.00340	0.00233		
			103	100		
			0.00677	0.00473		
			146	100		
			0.01750	0.01428		
			115	100		



another flat surface. The time for the motions grasp, transport loaded and position, and release load and transport empty was measured very accurately. Circular washers  $\frac{1}{2}$  inch in diameter, with a  $\frac{1}{8}$ -inch hole in the center, and  $\frac{1}{32}$ ,  $\frac{1}{8}$ ,  $\frac{1}{4}$ , and  $\frac{1}{2}$  inch thick were used.

The time for grasp using the hook grasp tended to increase slightly as the washer thickness increased, whereas the time for grasp using the pressure grasp decreased markedly as the washer thickness increased. The time for grasping the thinnest washer ( $\frac{1}{32}$  inch thick) using a pressure grasp was 297 per cent greater than when grasping the thickest washer ( $\frac{1}{2}$  inch thick).<sup>5</sup>

It is usually quicker and easier to transport small objects by sliding than by carrying. In grasping a small object such as a coin or a washer preparatory to transporting it by sliding, the grasp consists merely of touching the ball of the index finger to the top surface of the object. Whereas, in grasping the same object preparatory to transporting it by carrying, the grasp consists of closing the thumb and index finger around the piece. A recent study<sup>6</sup> showed that the grasp preceding the slide required as little as one-thirtieth as long as the grasp preceding the carry. The data pertaining to this point are given in Table VI, see p. 154.

### Check List for Grasp

1. Is it possible to grasp more than one object at a time?
2. Can objects be slid instead of carried?
3. Will a lip on front of the bin simplify grasp of small parts?
4. Can tools or parts be pre-positioned for easy grasp?
5. Can a special screwdriver, socket wrench, or combination tool be used?
6. Can a vacuum, magnet, rubber finger tip, or other device be used to advantage?
7. Is the article transferred from one hand to another?

<sup>5</sup> This investigation and the others carried on in the Industrial Engineering Laboratory at the University of Iowa and referred to in this book were made with most meticulous care, and the data were taken with all the accuracy obtainable with the measuring devices that were used. However, the point must be noted that certain inevitable variations were introduced as a result of the fact that the movements being measured were those of human, as distinct from purely mechanical subjects. The results given here are presented, not as general conclusions but merely as the findings of specific studies, details of which are fully described in the publications referred to in the footnotes.

<sup>6</sup> *University of Iowa Studies in Engineering, Bulletin 6*, p. 32.



TABLE VI

TIME REQUIRED TO GRASP SMALL WASHERS  
(Grasp preceding carry and grasp preceding slide)

Time in Minutes

Object Grasped	Study X74 Grasp Preceding Carry	Study X75 Grasp Preceding Slide
Rubber washer	0.00960	0.00033
Steel washer	0.00895	0.00031
Lock washer	0.00750	0.00038

8. Does the design of the jig or fixture permit an easy grasp in removing the part?

**Transport Empty and Transport Loaded.** Investigations<sup>7</sup> show (1) that it requires a greater period of time to move the hand through a long distance than through a short distance, other conditions being constant; (2) that the average velocity of the hand is greater for long motions than for short ones; and (3) that in such motions as transport empty and transport loaded the hand of an experienced operator moves through almost identically the same path in going from one point to another in consecutive cycles of a repetitive operation. The particular study relating to this last point was made by projecting the film, one frame at a time, on a sheet of paper and marking the position of the tip of the index finger. Connecting these points by pencil lines gave the path of the motion in two dimensions. By placing the camera perpendicular to the path of motion it was possible to secure a close approach to a true record of the motion path.

Table XVI on page 217 shows the results of some studies made of the operation of moving small pieces of wire through distances of 8, 16, and 24 inches in forming links for a typewriter.

A movement of the hand, such as transport empty or transport loaded, is ordinarily composed of three phases: (1) the hand, starting from a still position, accelerates until it reaches a maximum velocity; (2) it then proceeds at a uniform velocity; and (3) finally the hand slows down until it comes to a dead stop. If the hand changes direc-

<sup>7</sup> *University of Iowa Studies in Engineering, Bulletin 6, p. 23, 1936.*



tion and returns over the same path, as in making a mark back and forth across a sheet of paper, there will be an appreciable length of time at the end of the stroke during which the hand is motionless, that is, while the hand is changing direction.<sup>8</sup>

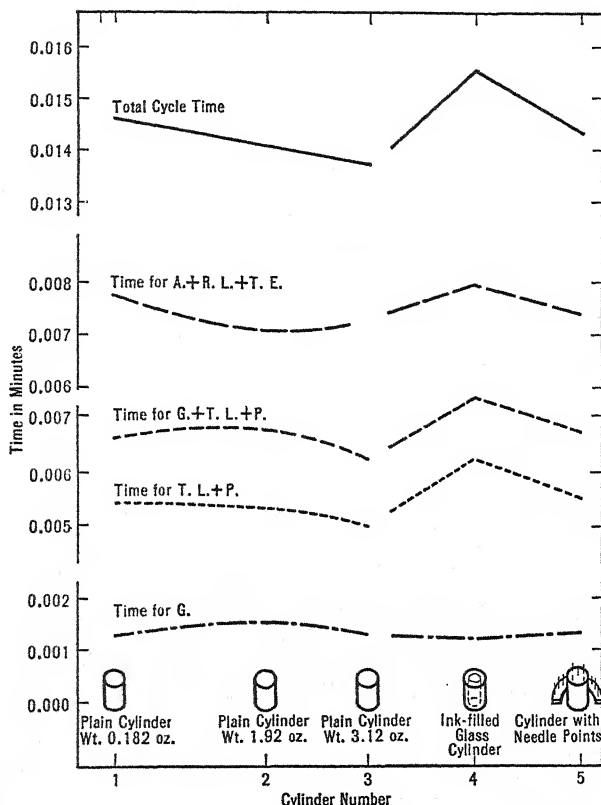


FIG. 92. Curves showing results of study of time required to grasp various small cylinders from a flat surface. Averages of median time values for five male and five female operators are shown.

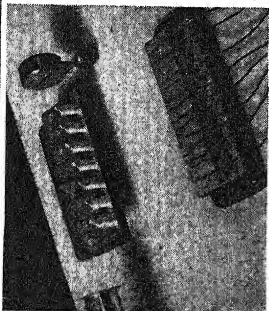
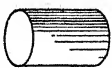


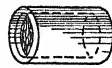
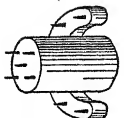
For example, in a simple hand motion 10 inches in length one study<sup>9</sup> showed the distribution of these events to be as follows: 38 per cent of the cycle time for acceleration, 18 per cent for movement at uniform velocity, 27 per cent for retardation, and 17 per cent for stop and change direction. See Fig. 136 on page 220.

<sup>8</sup> *Ibid.*, pp. 37-51.

<sup>9</sup> *Ibid.*, p. 48.



TABLE VII  
TIME REQUIRED TO GRASP VARIOUS SMALL CYLINDERS FROM A FLAT SURFACE

	GRASP Pick up cylinder from "Grasp" grid shown above.	Time in Minutes	 Plain Cylinder Wt., 0.182 oz.	 Plain Cylinder Wt., 1.92 oz.	 Plain Cylinder Wt., 3.12 oz.	 Ink-Filled Glass Cylinder	 Cylinder with Needle Points
		Time in Per Cent (Shortest Time = 100%)	0.00128 107	0.00151 126	0.00126 106	0.00120 100	0.00128 107
		Time in Minutes	0.00551	0.00540	0.00505	0.00631	0.00557
		Time in Per Cent (Shortest Time = 100%)	109	107	100	125	110
		Time in Minutes	0.00679	0.00691	0.00631	0.00751	0.00685
GRASP, TRANSPORT LOADED AND POSITION	TRANSPORT LOADED AND POSITION Carry cylinder through a distance of 5 inches and place on special "Release" grid.	Time in Per Cent (Shortest Time = 100%)	107	110	100	119	108
		Time in Minutes	0.01460	0.01403	0.01367	0.01552	0.01430
		Time in Per Cent (Shortest Time = 100%)	107	103	100	113	105
TOTAL CYCLE (G. + T. L. + P. + A. + R. L. + T. E.)		Time in Minutes					
		Time in Per Cent (Shortest Time = 100%)					



The time required to move the hand is affected by the nature of the motions which precede and which follow the transport. For example, when a delicate or fragile object is transported and placed carefully in a small receptacle, the time for the transport will be longer than when the transport is followed by an ordinary disposal such as tossing a bolt into a box.

The manner in which an object is grasped and the way that it must be carried and positioned may also affect the time for the transport. This is shown by the results of an investigation<sup>10</sup> made to determine

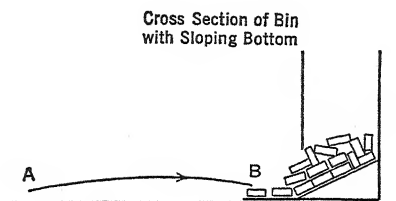


FIG. 93. Straight-line motion of the hand. The hand moves from A to B to pick up a washer which rests on the lip of the bin. The cross section of the bin shows sloping bottom which feeds washers forward.

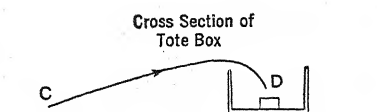


FIG. 94. A longer hand motion is required because the hand must reach down into box to get washer. The side of the box forms a barrier, making it necessary for the hand to change direction in going from C to D.

the time required to grasp various small cylinders from a flat surface. The results of this study are given in Fig. 92 and Table VII.

The operator picked up a cylinder from one flat surface, carried it through a distance of 5 inches, and placed it on another flat surface, sliding it between two small flat copper springs. The time for the motions grasp, and transport loaded and position was measured very accurately. Five cylinders  $2\frac{3}{32}$  inch in diameter and 1 inch high were used. Three of these were identical except for weight. Cylinder 1 weighed 0.184 ounce, cylinder 2, 1.92 ounces, and cylinder 3, 3.12 ounces. Cylinder 4 was a glass cup filled with ink, and cylinder 5 was a brass cylinder identical in size and weight with 2 but studded on top with needle points.

To transport loaded and position the heaviest of the cylinders (3) required the least time. The lightest cylinder (1) required 9 per cent more time, the solid brass cylinder (2) 7 per cent more time, the ink-filled glass cylinder 25 per cent more time, and the cylinder with the needle points 10 per cent more time than did cylinder 3.

<sup>10</sup> University of Iowa Studies in Engineering, Bulletin 16, p. 20, 1939.



The path of the hand in reaching for a small washer is shown in Figs. 93 and 94. The time to move the hand from *A* to *B* is less than that required to move the same distance from *C* to *D* because of the change in direction of the hand in the latter case. Barriers and obstructions that retard free hand motion or that require a change in direction should be eliminated whenever possible.

**Gauging Hard Rubber Washers.** Mention has already been made of the fact that it is usually quicker and easier to transport small objects by sliding than by carrying. That a "grasp and slide" is definitely faster than a "grasp and carry" apparently results from the shorter grasp rather than from a saving in time in the transportation.

The inspection of small hard rubber washers for thickness is another illustration of the use of a sliding transport. The gauge used for this operation was developed by W. R. Mullee while at the American Hard Rubber Company. The purpose of this operation is to reject all washers that are too thick or too thin as well as those having burrs on the edges. The washers have the following dimensions: outside diameter  $0.280 \pm 0.002$  inch, inside diameter  $0.188 \pm 0.002$  inch, and thickness  $0.085 \pm 0.005$  inch.

The metal bar *A* forms a "go" gauge and the bar *B* a "no-go" gauge with the base *C*, which is a heavy metal plate set at an angle with the bench top. The washers to be inspected are drawn from the hopper *D* by hand into the upper section of the inclined go gauge. Those washers that do not slide underneath the bar *A* are too thick and are slid in multiple to the chute *E* at the left of the gauge. The pieces that go through the gauge *A* drop down into the middle compartment. If they are too small they slide under the gauge *B* and drop into the box *F* directly in front of the operator. Washers that are the correct size are slid off into the chute *G* at the right. (See Fig. 95.)

All movements of the washers in this operation are sliding transports. The washers are not picked up at any place in the cycle. They are not handled individually but are shuffled back and forth in groups across the metal plate and against the bar gauges so that gravity is able to act as the force which tends to pull them through the gauge.

The height and angle at which the gauge is mounted above the bench are such as to make the task as easy and comfortable as possible. With this arrangement one operator inspects 30,000 washers per day.



**Effect of Eye Movements on Transport Time.** In any activity where the eyes must direct the hands the eye movements and eye fixations often control the operation. In such work it is necessary to study the relationship of the eye movements to the hand motions.

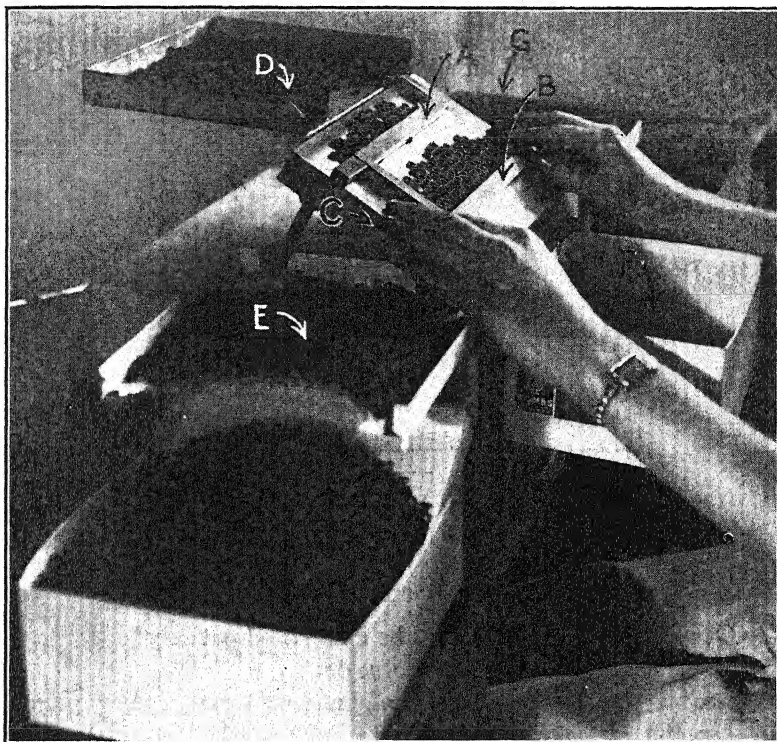


FIG. 95. Special gauge for inspecting hard rubber washers for thickness. A. Go gauge; B. No-go gauge; C. Base place of gauge; D. Supply of washers; E. Rejected washers (oversize); F. Rejected washers (undersize); G. Good washers.

A study<sup>11</sup> was made to obtain information bearing on the question "How are eye and hand movements coordinated when simultaneous symmetrical motions are performed?" A simple operation of picking up a washer in each hand and placing them, bright side up, on two vertical pins in the center of the work place (see Fig. 96) was used for the investigation. Nine different operators did the job, and careful records were made of eye and hand movements by means of an eye-movement camera. Figure 97 is an eye-hand simo chart of one cycle

<sup>11</sup> Study made by D. U. Greenwald in the University of Iowa Industrial Engineering Laboratory.



of the operation. The results of this study showed that in reaching for the washers in the two bins, the eyes went first to the right bin, then to the left bin, and finally to the center pins. In most cases the eyes led the hands to the bins and also to the pins. In this operation it seemed to make no difference whether the eyes were focused on the right pin or the left pin. Apparently the eyes could direct the hands equally well when focused on either pin.

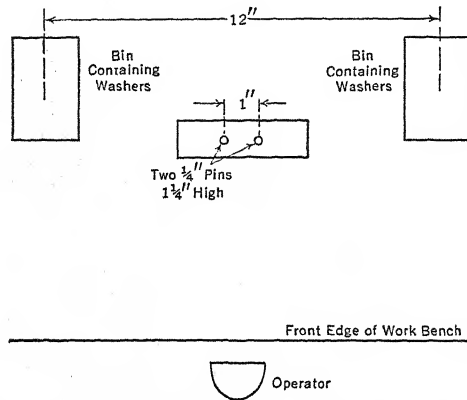


FIG. 96. Layout of work place for the assembly of washers onto pins.

### Check List for Transport Empty and Transport Loaded

1. Can either of these motions be eliminated entirely?
2. Is the distance traveled the best one?
3. Are the proper means used, i.e., hand, tweezers, conveyors, etc.?
4. Are the correct members (and muscles) of the body used, i.e., fingers, forearm, shoulder, etc.?
5. Can a chute or conveyor be used?
6. Can "transports" be effected more satisfactorily in larger units?
7. Can transport be performed with foot-operated devices?
8. Is transport slowed up because of a delicate position following it?
9. Can transports be eliminated by providing additional small tools and locating them near the point of use?
10. Are parts that are used most frequently located near the point of use?
11. Are proper trays or bins used, and is the operation laid out correctly?
12. Are the preceding and following operations properly related to this one?



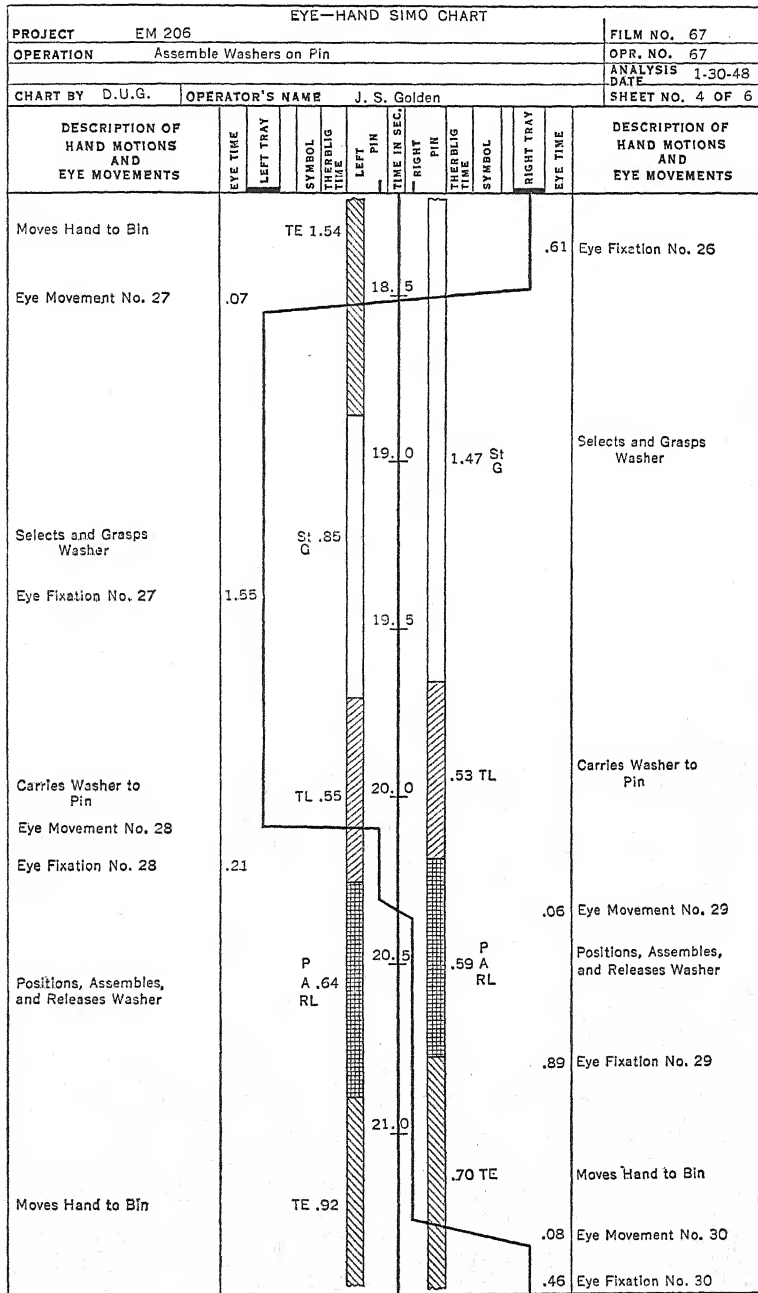


Fig. 97. Eye-hand simo chart for one cycle of an assembly operation.



13. Is it possible to eliminate abrupt changes in direction? Can barriers be eliminated?
14. For the weight of material moved, is the fastest member of the body used?
15. Are there any body movements that can be eliminated?
16. Can arm movements be made simultaneously, symmetrically, and in opposite directions?
17. Can the object be slid instead of carried?
18. Are the eye movements properly coordinated with the hand motions?

**Hold.** Hold is a therblig that frequently occurs in assembly work and in hand-manipulated machine operations. It is one of the easiest therbligs to eliminate and often leads to substantial increases in output. The elimination of the hold therblig in the bolt and washer assembly (see page 194), for example, was largely responsible for the 50 per cent increase in output.

The hand should not be used for a "vise"—a mechanical device of some kind is usually much more economical for holding. In fact, when one hand is used for holding, the operator has reduced his capacity for productive hand work by 50 per cent. Although not every hold therblig can be eliminated, certainly all such therbligs in a cycle are vulnerable points of attack for improving the method.

#### Check List for Hold

1. Can a vise, clamp, clip, vacuum, hook, rack, fixture, or other mechanical device be used?
2. Can an adhesive or friction be used?
3. Can a stop be used to eliminate hold?
4. When hold cannot be eliminated can arm rests be provided?

**Release Load.** Although release load is often of very short duration, it should always be included in the analysis. In the operation "assemble bolt and washers" described on page 194 the operator released the washer after having assembled it onto the bolt. This motion required such a short time that it could not be measured with the clock at ordinary speeds, and consequently this motion was combined with the preceding one as shown in Fig. 80.

Release load should be short. If it is of long duration some change should be made in the operation to shorten it. The discussion on page 251 under drop delivery suggests some possible changes.



**Check List for Release Load**

1. Can this motion be eliminated?
2. Can a drop delivery be used?
3. Can the release be made in transit?
4. Is a careful release load necessary? Can this be avoided?
5. Can an ejector (mechanical, air, gravity) be used?
6. Are the material bins of proper design?
7. At the end of the release load, is the hand or the transportation means in the most advantageous position for the next motion?
8. Can a conveyor be used?

**Position and Pre-position.** The difference between position and pre-position may be illustrated by the simple operation of picking up a fountain pen, writing, and returning it to its holder.<sup>12</sup> The motions involved in this operation are shown in Table VIII below.

TABLE VIII  
MOTIONS USED IN WRITING

Steps Used in Writing	Name of Motions	Time in Thousandths of a Minute
1. Reaches for pen	Transport empty    TE	10
2. Grasps pen	Grasp    G	3
3. Carries pen to paper	Transport loaded    TL	8
4. Positions pen for writing	Position    P	3
5. Writes	Use    U	44
6. Returns pen to holder	Transport loaded    TL	9
7. Inserts pen in holder	Pre-position    PP	6
8. Lets go of pen	Release    RL	1
9. Moves hand to paper	Transport empty    TE	9

After the pen is carried to the paper it is necessary to *position* it, that is, to bring the pen down on the sheet of paper at the correct place on the line to begin writing. This is a *position* motion. The writing completed, the pen is returned to the holder. The motion *transport loaded* is followed by *pre-position* (rather than by position) because the pen rests in the holder in such a way that it can be

<sup>12</sup> This refers to the usual form of fountain-pen desk set.







grasped in the position in which it will be used the next time. Had the pen been placed in a horizontal pen holder on the desk top, the motion sequence would then have been *transport loaded* and *position* (rather than pre-position) because the pen would have been resting in such a way that it could not have been grasped in the correct position for using. However, had the pen merely been dropped on the desk top the motion sequence would have been *transport loaded* and *release load* since no positioning or pre-positioning would have occurred.

**Positioning Pins in Bushings with Beveled Holes.** Beveled holes in bushings, funnel-shaped openings in fixtures, and bullet-nosed pins all tend to reduce positioning time.

The results of a study<sup>13</sup> of the time required to position and insert pins in bushings with beveled holes are given in Figs. 98 and 99 and Table IX.

The operation consisted of grasping a quarter-inch brass pin  $1\frac{1}{4}$  inches long from a magazine, carrying it through a distance of 5 inches, positioning and inserting it in the hole in the bushing, withdrawing the pin, and disposing of it in a tray on the table top. The time for the motions transport loaded, position, and assemble and disassemble was accurately measured.

The study was conducted in two parts, one where the clearance between the pin and the hole in the bushing was 0.002 inch, and the other where the clearance was 0.010 inch.

Least time was required to position the pin in the bushing with the 45-degree bevel (1). Seventy-three per cent more time was required to position the pin in the bushing with no bevel (5) when the clearance was 0.002 inch.

**Positioning Bars on Pins.** The results of another study<sup>14</sup> similar to the preceding one are shown in Figs. 100 and 101 and Table X.

The operation consisted of grasping a flat bar  $\frac{1}{8}$  inch thick,  $\frac{5}{8}$  inch wide, and 3 inches long, removing it from two pins near the front edge of the table, carrying it through a distance of 5 inches, positioning it on two accurately machined pins (called a "pin set"), and dropping it over the pins. The time for the motions transport loaded and position was accurately measured.

The study was conducted in two parts, one where the clearance between the pin and the hole in the bar was 0.003 inch, and the other where the clearance was 0.011 inch.

<sup>13</sup> University of Iowa Studies in Engineering. *Bulletin* 12. p. 19, 1938.

<sup>14</sup> *Ibid.*, p. 31.



The results of the study are shown in Table X. For example, least time was required to position the bar over the pins with the bullet nose (4). The pins with the square ends (2) required approximately 156 per cent more time with a clearance of 0.003 inch.

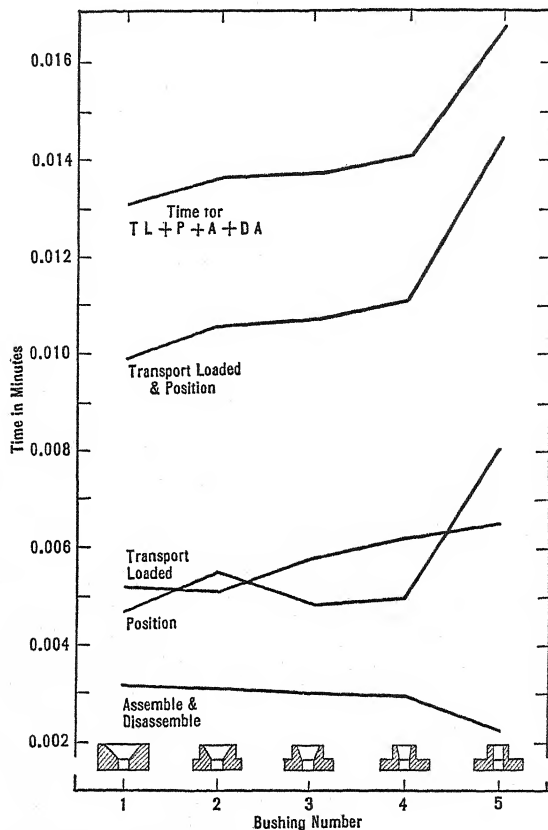


FIG. 98. Curves showing results of study of time required to position pins in beveled holes when the clearance between the pin and the hole in the bushing was 0.002 inch. Averages of median time values for seven male operators are shown.

**Positioning Blocks in Slots.** A study<sup>15</sup> was made by John M. MacKenzie to determine the time required to position and release small wood blocks ( $\frac{1}{2}$  inch cubes) in slots with varying amounts of clearance.

<sup>15</sup> University of Iowa Studies in Engineering, *Bulletin* 21, 1940.



The operation consisted of selecting and grasping a block from a rectangular container, carrying it through a distance of 5 inches, and inserting it in a slot in a mask and releasing it. All the slots were  $3\frac{1}{2}$  inches long and the clearance was varied as follows:  $\frac{1}{64}$ ,  $\frac{1}{32}$ ,

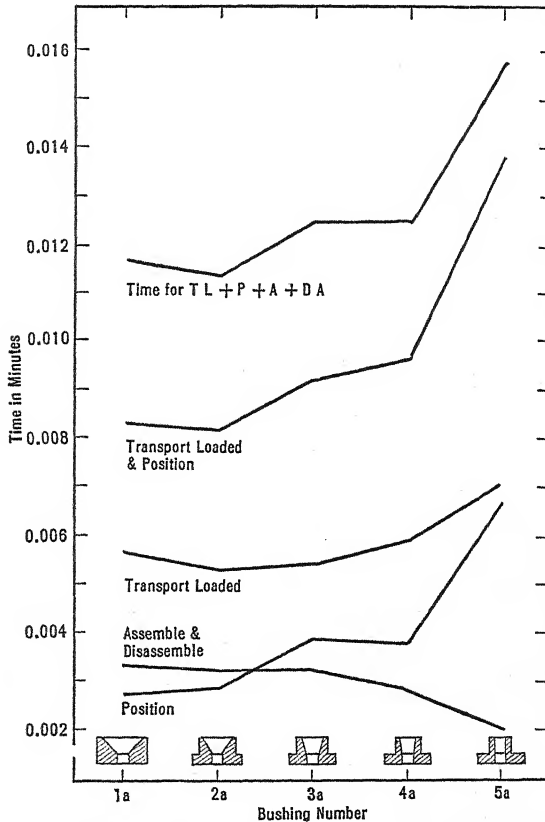


FIG. 99. Curves showing results of study of time required to position pins in beveled holes when the clearance between the pin and the hole in the bushing was 0.010 inch. Averages of median time values for seven male operators are shown.

$\frac{1}{16}$ ,  $\frac{1}{8}$ , and  $\frac{3}{8}$  inch. The latter slot permitted the block to be dropped through without lining the sides up with the sides of the slot. In the first part of the study the slot was placed vertical or perpendicular with the front edge of the work table and in the second part of the study it was placed horizontal or parallel with the front edge.



The results of the study given in Fig. 102 and Table XI show that in general, for a given set of conditions, a decrease in the minimum clearance between the block and the disposal opening causes an increase in the position plus release load time. It takes 151 per cent

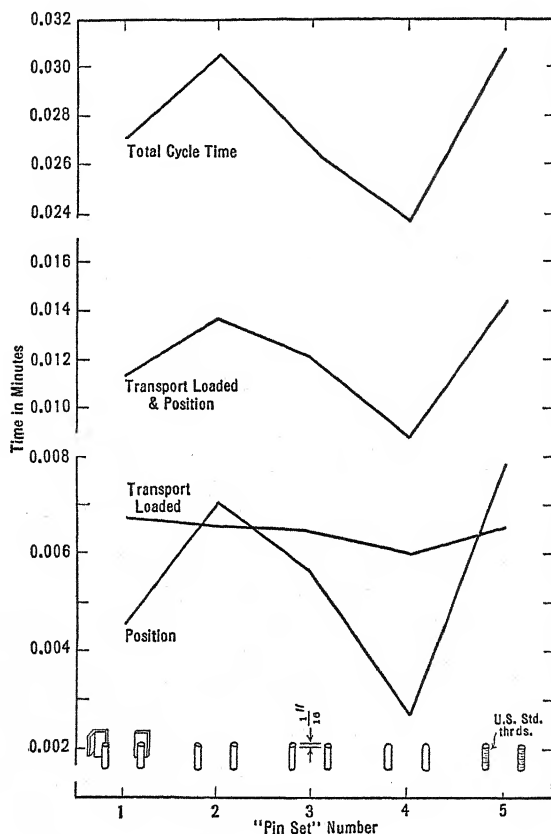


FIG. 100. Curves showing results of study of time required to position bars on five different pin sets when the clearance between the pins and the holes in the bar was 0.003 inch. Averages of median time values for ten male operators are shown.

more time to position and release a block, both hands being used and slots vertical, when there is a clearance of  $\frac{1}{64}$  than it does when there is a clearance of  $\frac{3}{8}$  of an inch.

For a given set of conditions, the time required for position plus release load when using both hands is 25 per cent greater than the



time required when using one hand alone. However, two blocks are being carried instead of one.

Some devices which aid in pre-positioning tools and materials are shown on pages 294 and 295.

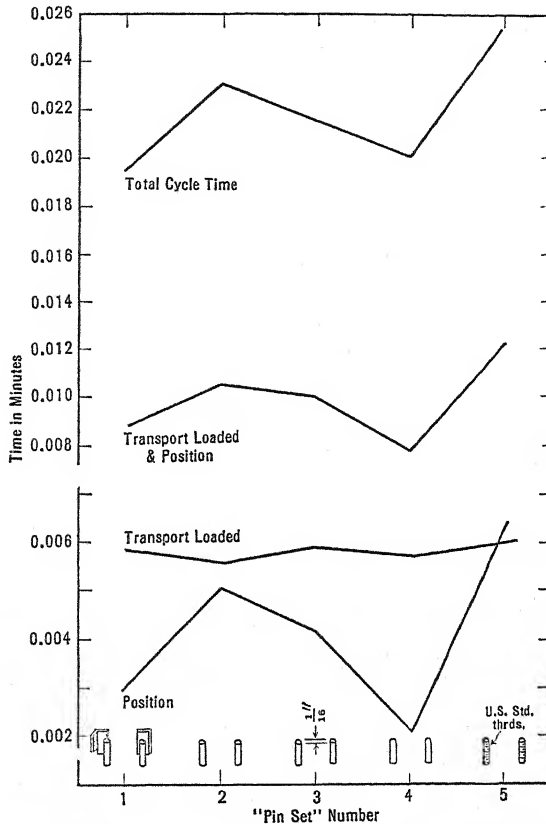


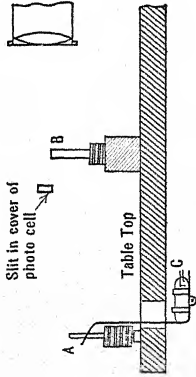
FIG. 101. Curves showing results of study of time required to position bars on five different pin sets when the clearance between the pins and the holes in the bar was 0.011 inch. Averages of median time values for ten male operators are shown.

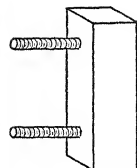
### Check List for Position

1. Is positioning necessary?
2. Can tolerances be increased?
3. Can square edges be eliminated?

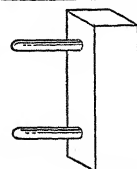


TABLE X  
TIME REQUIRED TO POSITION BARS ON PINS

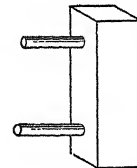
 <p>Slit in cover of photo cell</p> <p>Table Top</p> <p>A</p> <p>B</p> <p>C</p>	<p>TRANSPORT LOADED</p> <p>Carry bar from supply at A (see figure above) to the pin set at B.</p>	<p>Time in Minutes</p> <p>Time in Per Cent (Shortest Time = 100%)</p>	Clearance Between the Pin and the Hole in the Bar in Inches									
			0.003	0.011	0.003	0.011	0.003	0.011	0.003	0.011	0.003	0.011
			0.00679	0.00587	0.00657	0.00557	0.00645	0.00535	0.00600	0.00567	0.00654	0.00590
			113	105	109	100	108	105	100	102	109	106
			0.00452	0.00302	0.00706	0.00302	0.00552	0.00410	0.00275	0.00198	0.00785	0.00614
<p>POSITION</p> <p>Place bar on pin set at B.</p>	<p>Time in Minutes</p> <p>Time in Per Cent (Shortest Time = 100%)</p>	<p>Time in Minutes</p> <p>Time in Per Cent (Shortest Time = 100%)</p>	0.01131	0.00889	0.01363	0.01059	0.01197	0.00905	0.00875	0.00765	0.01439	0.01204
			129	116	156	138	137	130	100	100	164	157
			0.02705	0.01960	0.03051	0.02312	0.02647	0.02147	0.02362	0.01995	0.03082	0.02527
			115	100	129	118	112	110	100	102	131	129
			0.02705	0.01960	0.03051	0.02312	0.02647	0.02147	0.02362	0.01995	0.03082	0.02527
<p>TRANSPORT LOADED AND POSITION</p>	<p>Time in Minutes</p> <p>Time in Per Cent (Shortest Time = 100%)</p>	<p>Time in Minutes</p> <p>Time in Per Cent (Shortest Time = 100%)</p>	0.01131	0.00889	0.01363	0.01059	0.01197	0.00905	0.00875	0.00765	0.01439	0.01204
			129	116	156	138	137	130	100	100	164	157
			0.02705	0.01960	0.03051	0.02312	0.02647	0.02147	0.02362	0.01995	0.03082	0.02527
			115	100	129	118	112	110	100	102	131	129
			0.02705	0.01960	0.03051	0.02312	0.02647	0.02147	0.02362	0.01995	0.03082	0.02527
<p>TOTAL CYCLE</p> <p>(T. L. + P. + A. + R. L. + T. E. + G. + D. A.)</p>	<p>Time in Minutes</p> <p>Time in Per Cent (Shortest Time = 100%)</p>	<p>Time in Minutes</p> <p>Time in Per Cent (Shortest Time = 100%)</p>	0.01131	0.00889	0.01363	0.01059	0.01197	0.00905	0.00875	0.00765	0.01439	0.01204
			129	116	156	138	137	130	100	100	164	157
			0.02705	0.01960	0.03051	0.02312	0.02647	0.02147	0.02362	0.01995	0.03082	0.02527
			115	100	129	118	112	110	100	102	131	129
			0.02705	0.01960	0.03051	0.02312	0.02647	0.02147	0.02362	0.01995	0.03082	0.02527



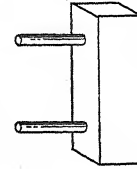
5  
Threaded pins of equal height with square ends.



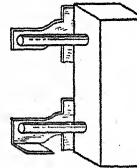
4  
Pins of equal height with round ends.



3  
Pins of unequal height with square ends.



2  
Pins of equal height with square ends.

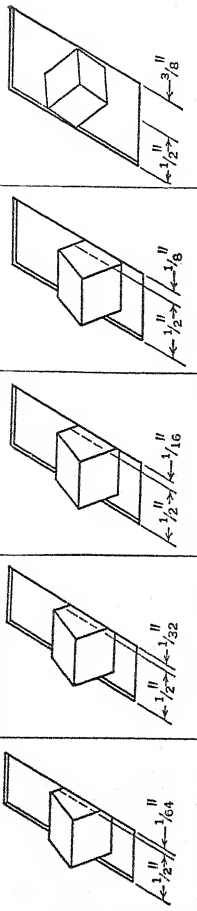
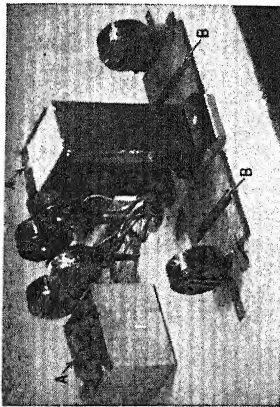


1  
Pins of equal height with square ends. Guides at left end and back.



TABLE XI  
TIME REQUIRED TO POSITION AND RELEASE SMALL BLOCKS IN SLOTS WITH VARYING AMOUNTS OF CLEARANCE

POSITION AND RELEASE	Time in Minutes	Time in Per Cent (Shortest Time = 100%)	Position of Slot Relative to Front Edge of Work Table									
			Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal
POSITION AND RELEASE Place block through slot in mask at B and release.	Time in Minutes	Time in Per Cent (Shortest Time = 100%)	0.01380	0.01215	0.01340	0.01188	0.01013	0.00993	0.00922	0.00843	0.00713	
			251	170	244	167	185	139	168	100	100	
			0.03367	0.03127	0.03307	0.03013	0.02927	0.02708	0.02750	0.02182	0.02303	
TOTAL CYCLE Select and grasp block from container A above, carry block 5 inches, insert in slot in mask at B, and release.	Time in Minutes	Time in Per Cent (Shortest Time = 100%)	154	136	152	131	134	118	126	100	100	
			0.00893	0.00110	0.00875	0.00983	0.00698	0.00858	0.00793	0.00445	0.00525	
			201	210	197	187	157	163	178	100	100	
POSITION AND RELEASE Place block through slot in mask at B and release.	Time in Minutes	Time in Per Cent (Shortest Time = 100%)	0.02205	0.02270	0.02095	0.02263	0.02075	0.02090	0.02010	0.01528	0.01667	
			144	136	137	136	136	125	131	100	100	





4. Can a guide, funnel, bushing, gauge, stop, swinging bracket, locating pin, spring, drift, recess, key, pilot on screw, or chamfer be used?

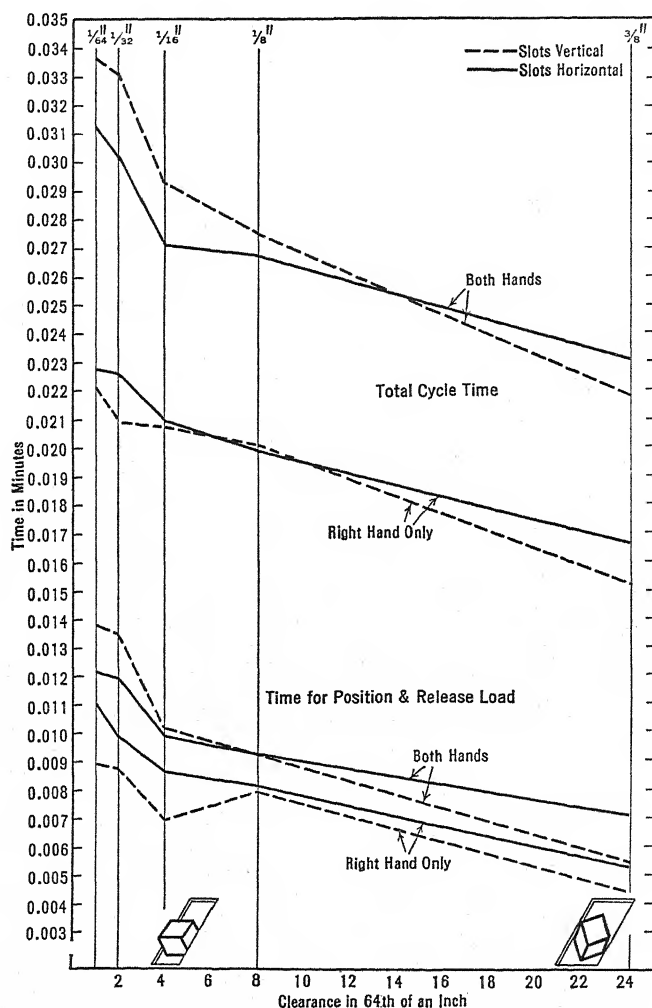


FIG. 102. Curves showing the results of study of time required to position blocks in slots. Averages of median time values for five male operators are shown.

5. Can arm rests be used to steady the hands and reduce the positioning time?



6. Has the object been grasped for easiest positioning?
7. Can a foot-operated collet be used?

#### Check List for Pre-position <sup>16</sup>

1. Can the object be pre-positioned in transit?
2. Can tool be balanced so as to keep handle in upright position?
3. Can holding device be made to keep tool handle in proper position?
4. Can tools be suspended?
5. Can tools be stored in proper location to work?
6. Can a guide be used?
7. Can design of article be made so that all sides are alike?
8. Can a magazine feed be used?
9. Can a stacking device be used?
10. Can a rotating fixture be used?

**Inspect.** In inspection work <sup>17</sup> the time for the therblig inspect is usually proportional to the reaction time of the individual and the type of the stimulus used. Only an individual with fast reaction time should be employed on inspection operations. Incidentally, good eyesight is a second essential requirement for success on this kind of work.

As to the type of stimulus, the data in Table XII show that, other conditions being equal, a person would react more quickly to sound than to light, the time being 0.185 second for the former and 0.225 second for the latter. Reaction to touch is the quickest of all, being 0.175 second.<sup>18</sup>

#### Check List for Inspect

1. Can inspect be eliminated or overlapped with another operation?
2. Can multiple gauges or tests be used?
3. Can a pressure, vibration, hardness, or flash test be used?
4. Can the intensity of illumination be increased or the light sources rearranged to reduce the inspection time?

<sup>16</sup> Pre-position is discussed at length on pages 295 and 296.

<sup>17</sup> See also pages 264 to 271.

<sup>18</sup> A slight difference in reaction time results from different attitudes of mind on the part of the operator. For example, if the operator's mind is primarily concentrated on the *stimulus*, the reaction times are likely to be a little slower than those indicated. However, if his attention is primarily directed to the *muscular sensations* involved in reacting, the reactions will be a little faster.



TABLE XII  
AVERAGE SPEED OF REACTION  
Time in Thousandths of a Second

Type of Stimulus	Reaction Time
Simple reaction—visual stimulus. Subject was instructed to press telegraph key as quickly as possible after light flashed.	225
Simple reaction—auditory stimulus. Subject was instructed to press telegraph key as quickly as possible after electric buzzer sounded.	185
Simple reaction—touch stimulus. Subject was instructed to press telegraph key as quickly as possible after feeling bar touch hand.	175
Simple reaction—electric shock stimulus. Subject was instructed to press telegraph key as quickly as possible after receiving electric shock on hand.	140
Choice reaction—visual stimulus. Subject could react to two lights. If the right light flashed, the subject pressed the right key. If the left light flashed, the subject pressed the left key.	325
Timed action stimulus—touch stimulus. Subject is given notice of the approaching stimulus. The subject watched the operator's descending hand and was instructed to react as soon as the operator's hand touched the key.	50

5. Can a machine inspection be used to replace a visual inspection?
6. Can the operator use spectacles to advantage?

**Assemble, Disassemble, and Use.** The following explanation is included here to clarify the meaning of assemble and use. Use always refers to the use of a tool or device for the purpose for which it was intended. Thus, the actual writing (see Table VIII) was a use therblig. Similarly, painting, drilling, and sawing are all use therbligs. If a nut is assembled onto a bolt by hand this motion is assemble; whereas if a wrench is used for this operation the sequence is assemble (fit wrench to nut), use (turn nut down), and disassemble (remove wrench from nut).

Frequently a tool will be held in the palm of the hand when not in use. For example, the clerk checking boxes in a shipping department may place a crayon mark on certain items as they pass by on a conveyor. The use therblig would not include the entire cycle but only that part during which the crayon is actually used for marking.



The use of the bone in folding paper presents another example of this. See page 222.

Some analysts advocate limiting *use* to ultimate objectives and restricting assemble to such temporary acts as fitting a tool to its work. Thus, any permanent assembly of two or more parts would be *use* even when no tool is involved.<sup>19</sup> Since this interpretation is likely to result in some confusion to the beginner, and in view of the fact that the former interpretation is more widely accepted, use will, in this book, always refer to the use of a tool or device for the purpose for which it was intended; and assemble will be understood to consist of placing one object into or onto another object with which it becomes an integral part.

**Painting with Spray Gun.** The scope of the use therblig is so wide that it is impossible to cite representative cases. However, one illustration will be included because it gives an interpretation of this therblig that is often overlooked. The operation is painting with a spray gun the enclosed motor unit of an electric refrigerator. The unit had a number of irregular projections and, since it occupied a prominent position on the refrigerator, a first-class painting job was required. From observation of the operation it was apparent that the operator was wasting paint, because he was missing the surface, "spraying air" by spraying past corners, and making sweeping flourishes during which little or none of the paint was being directed at the refrigerator unit. In this operation the use motion not only involved time but material as well. Therefore, shortening the use motion meant saving both time and paint.

A micromotion study of this operation, made of the best operator in the plant, showed that during 23 per cent of the time the spray gun was in use the paint was not hitting the surface of the unit being sprayed, but was being wasted "spraying air."

By careful training of the operator, and by some changes in the work place, including a power-driven, foot-controlled turntable for the work and three fixed spray guns mounted above the turntable, the following results were obtained:

(a) Savings in time	50 per cent
(b) Reduction in rejects	60 per cent
(c) Direct labor savings per year	\$3750.00
(d) Savings in paint per year	\$5940.00
(e) Cost to develop and install new method	\$1040.00

<sup>19</sup> L. P. Alford and J. R. Bangs, Jr., Eds., "Production Handbook," p. 577, Ronald Press, New York, 1944.



Not only did the total savings in direct labor and paint resulting from the improved method amount to a substantial sum, but also of importance was the great reduction in rejects. In the old method of spraying most of the rejects resulted from "runs" in the paint. In such cases the excess paint had to be scraped off and the unit repainted, which was an expensive operation. The improved method eliminated most of this type of reject.

#### Check List for Assemble, Disassemble, and Use

1. Can a jig or fixture be used?
2. Can an automatic device or machine be used?
3. Can the assembly be made in multiple? Or can the processing be done in multiple?
4. Can a more efficient tool be used?
5. Can stops be used?
6. Can other work be done while machine is making cut?
7. Should a power tool be used?
8. Can a cam or air-operated fixture be used?

#### ACCURATE MEASUREMENT OF FUNDAMENTAL MOTION TIME

The motion time values for several of the investigations referred to in this chapter were given in hundred thousandths of a minute. An electrical recording kymograph (see Fig. 103) was used for making these time measurements.

Paper tape, similar to adding-machine tape, is drawn across the kymograph table by means of the two rollers shown at the front of the machine. A synchronous motor drives the rollers, drawing the paper through at a uniform velocity of 2000 inches per minute.

Solenoid-operated pens are mounted above the paper tape so that each of the pens makes contact with it and draws a straight line on the tape as it passes through.

Each pen is connected to a solenoid in such a way that closing the solenoid circuit jerks the pen toward the solenoid and perpendicular to the motion of the paper through the kymograph, thus putting a jog in the ink line on the moving tape (see Fig. 104).

Figure 104 is a reproduction of the record made by the solenoid-operated pens for the study of grasping washers of varying thickness.

Washers were placed in a row on the grid shown in Table V (see also Table VII), a thin flat beam of light was passed across the top of the row of washers, and allowed to fall on a photoelectric cell



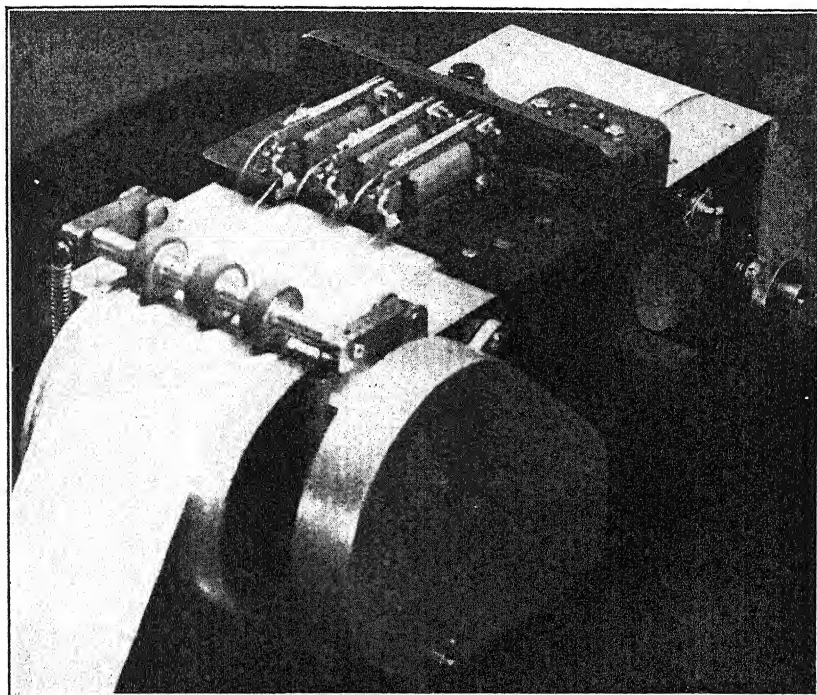


FIG. 103. Electrically operated kymograph measures and records time. Paper tape passes through the machine at a uniform speed of 2000 inches per minute, and solenoid-operated pens mounted above the tape may be used to mark the beginning and end points of therbligs or of other subdivisions of an operation to be timed.

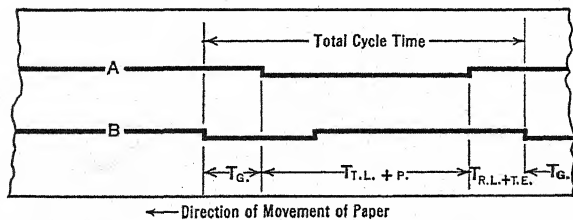


FIG. 104. Reproduction of record made by solenoid-operated pens on kymograph for study of grasping washers of varying thickness.



mounted at the end of the grid. This photoelectric cell was connected through relays to pen *B* on the kymograph. As the finger and thumb interrupted the beam of light to grasp the washer the first jog in the line *B* was made, marking the beginning of the grasp motion.

Since the brass bars in the grid were insulated from each other by a thin fiber strip or spacer between the bars, a circuit could be closed by placing brass washers across the insulators (fiber strip) and thus

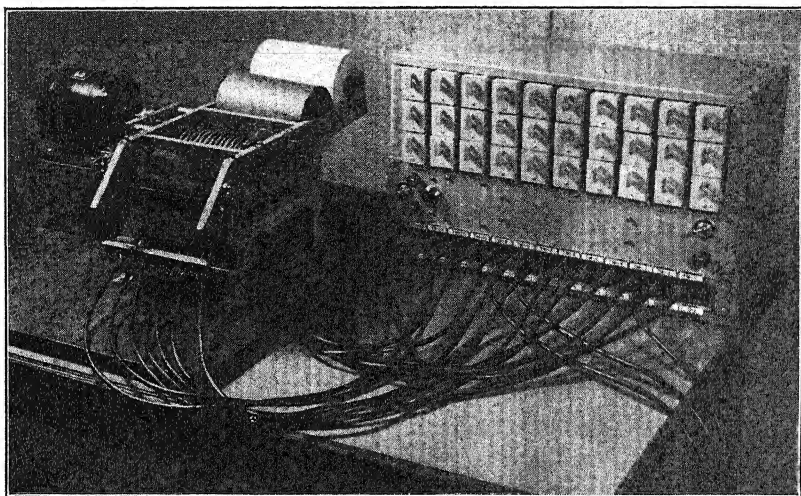


FIG. 105. Automatic time recorder prints time values in ten thousandths of a minute directly on paper tape.

connecting all grids together. Such a circuit was used and connected to solenoid *A*. Thus, when the washer rested on top of the grid and across the insulating strip, the circuit was closed and line *A* was drawn. However, as soon as the washer was grasped by the thumb and fingers and started to be removed from the grid, the circuit was interrupted and the first jog was made in line *A* in Fig. 104. The distance between the first two jogs was a measure of the time required to grasp the washer. One-fiftieth of an inch on the tape represented  $\frac{1}{100,000}$  of a minute.

By means of photoelectric cells and other devices it is possible to measure various parts of an operation without interfering in any way with the natural movements of the operator.

**Automatic Time Recorder.** Although the kymograph is a satisfactory device for measuring short time intervals for motion study work, it is a tedious and time-consuming task to measure the distance be-



tween the jogs in the lines on the paper tape. A new automatic time recorder (see Fig. 105), designed by Professor H. G. Thuesen, has just been built in the University of Iowa Laboratories.<sup>20</sup> This time recorder will print time values in ten thousandths of a minute directly on paper tape. Because of the ease with which short time intervals can be measured, this apparatus will greatly facilitate motion study research in the laboratory.

<sup>20</sup> Acknowledgment is made to L. E. Davis and to the Western Electric Company for their assistance in simplifying some of the design features of the recorder.



## CHAPTER 14

### FATIGUE

Since one of the main objectives of motion and time study is to reduce fatigue and to make the work as easy and satisfying for the individual as possible, it is desirable at this time to examine the nature of fatigue.

The term fatigue has various meanings depending upon the point of view that is taken in considering the subject. Fatigue in industry refers to three related phenomena:

1. A feeling of tiredness.
2. A physiological change in the body. The nerves and muscles fail to function as well or as fast as is normal because of chemical changes in the body resulting from work.
3. A diminished capacity for doing work.

**Feeling of Tiredness.** A feeling of tiredness is commonly associated with long periods of work. It is subjective in nature, and consequently the extent of tiredness cannot be determined by an observer. Tiredness may be localized in some particular muscle or it may be a general sensation of weariness.

This feeling of fatigue acts as a protective device in preventing exhaustion, but there is often no direct correlation with physiological fatigue which manifests itself in decreased ability to do work. A person may feel tired and yet he may work as efficiently as ever, or he may feel normal and yet he may be actually working at a low rate because of physiological fatigue. Therefore, the feeling of tiredness does not seem to be a valid basis for judging the effect of work on the individual.

**Physiological Changes Resulting from Work.** From the physiological point of view the human body may be thought of as a machine<sup>1</sup> which consumes fuel and gives out useful energy. The principal mechanisms of the body involved are (1) the circulatory system, (2) the digestive system, (3) the muscular system, (4) the nervous system, and (5) the respiratory system. Continuous physical work affects these mechanisms both separately and collectively.

<sup>1</sup> A. V. Hill, "Living Machinery," Harcourt, Brace and Co., New York, 1927.



Fatigue is the result of an accumulation of waste products in the muscles and in the blood stream which reduces the capacity of the muscles to act. Very possibly the nerve fiber terminals and the central nervous system may also be affected by work, thereby causing a person to slow up when tired. Muscular movements are accompanied by chemical reactions which require food for their activities. This food is furnished as *glycogen*, a starch-like substance which is carried in the blood stream and is readily converted into sugar. When the muscle contracts, the glycogen is changed into lactic acid, a waste product which tends to restrict the continued activity of the muscle. In the recovery phase of muscular action, oxygen is used to change most of the lactic acid back to glycogen, thus enabling the muscles to continue moving. The supply of oxygen and the temperature affect the speed of recovery. If the rate of work is not strenuous, the muscle is able to maintain a satisfactory balance. Excessive lactic acid does not accumulate and the muscle does not go into "oxygen debt," both of which diminish the capacity of the muscle to act.

An athlete running the mile might be used as an example of an individual exerting himself to the utmost. He is using the supply of fuel and oxygen at a rapid rate and therefore will require time for recuperation, that is, time to bring his muscles back to equilibrium.

The diagram in Fig. 106 shows the rate of oxygen consumption before, during, and after exercise.<sup>2</sup> The period of exercise is marked by the thick horizontal line. As the diagram shows, the rate of oxygen consumption starts to rise as soon as exercise begins and starts to fall as soon as it ceases. Since the exercise pictured in Fig. 106 was moderate, recovery was completed after a few minutes. After severe physical exercise, recovery may not be completed for an hour or more.

**Experiments in the Physiological Cost of Doing Work.** Physiologists have conducted many studies of physical work in which the energy expended was measured in terms of "physiological cost"<sup>3</sup> or the excess of oxygen consumed while the subject was working. Since

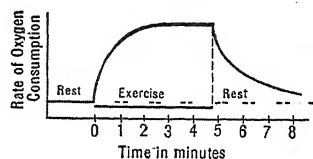


FIG. 106. Rate of oxygen consumption before, during, and after exercise. The period of exercise is marked by a heavy horizontal line.

<sup>2</sup> *Ibid.*, p. 142.

<sup>3</sup> "The physiological cost of a given piece of work is the amount of oxygen used during work and recovery in excess of the amount used during an equal period of time, the subject being in the resting state." G. P. Crowden, "The Physiological Cost of the Muscular Movements Involved in Barrow Work," Industrial Fatigue Research Board, *Report 50*, p. 2, 1928.



oxygen is used by man in proportion to the "fuel" burnt in his body, the amount of oxygen absorbed from the inhaled air during the period of work and recovery is a measure or an index of the extent of the vital process involved.<sup>4</sup>

The subject to be studied is fitted with apparatus (Douglas-Haldane Apparatus) for collecting exhaled air over a definite period of time. Usually the subject carries a mouthpiece in his mouth, so equipped with valves that fresh air is admitted from the outside and exhaled air is led through a tube to a large rubberized fabric bag carried on the back of the subject. A nose clip is placed on the nose so that breathing is possible only through the mouth. Using this technique, investigators have arrived at such conclusions as the following:

1. *Wheelbarrow Work:*<sup>5</sup>

(a) The optimum speed for wheeling a barrow is a normal brisk walk, as Table XIII shows.

TABLE XIII  
PHYSIOLOGICAL COST OF WHEELING BARROW AT VARIOUS RATES

	Slow Walk	Normal Brisk Walk	Very Quick Walk	Gentle Run
Excess O <sub>2</sub>	2520 cc.	2480 cc.	4040 cc.	3660 cc.
Relative values	1.01	1	1.63	1.47
Excess O <sub>2</sub>	2515 cc.	2280 cc.	4405 cc.	3887 cc.
Relative values	1.1	1	1.77	1.7
Excess O <sub>2</sub>	1560 cc.	1240 cc.	2040 cc.	1960 cc.
Relative values	1.26	1	1.64	1.58
Mean relative values	1.12	1	1.68	1.58

(b) The best conditions for barrow work are attained when the load is balanced to suit the worker's stature.

(c) Greatest energy is expended in starting and stopping, therefore the elimination of interruptions brings greater efficiency.

2. *Walking on Level:*<sup>6</sup>

(a) On a truly horizontal surface, the most economical rate of progress is 4.5 kilometres (2.8 miles) an hour. This enables an unburdened man to cover 45 to

<sup>4</sup> *Ibid.*, p. 2.

<sup>5</sup> *Ibid.*, p. 15. Table XIII reproduced by permission of the Controller of H. M. Stationery Office, London.

<sup>6</sup> Jules Amar, "The Physiology of Industrial Organization and the Reemployment of the Disabled," p. 133, Macmillan Co., New York, 1919.



50 kilometres (28 to 31 miles) in the day, with two minutes' rest at every kilometre.

(b) When the man is carrying a burden the economical pace, that which costs the organism least, is 4.2 kilometres (2.6 miles) an hour, the burden weighing from 20 to 22 kilogrammes (44 to 48.4 pounds). But to realize the maximum daily performance, the weight of the load should be 45 kilogrammes (99 pounds) and the rate of progress 4.8 kilometres (3 miles) an hour, while the day's work should consist of 7½ hours, with 2 minutes' rest every 600 metres (650 yards). An adult of 25 to 40 years of age can carry this load of 99 pounds for an average distance of 26 kilometres (16 miles) a day. But if the pace is increased to 5.5 kilometres (3.4 miles) an hour, the distance will be reduced by almost one-half, no matter how the intervals of rest may be arranged.

Durig states that the optimum speed is approximately eighty meters per minute (3 miles per hour) for a person walking on level ground.<sup>7</sup>

### 3. *Methods of Carrying Loads:*<sup>8</sup>

The best methods of carrying a load are those which interfere least with the normal body posture. Between the usual method and the best method there may be as much as 50 per cent difference.

### 4. *Performing Home Laundering Operations:*<sup>9</sup>

The energy cost of laundry processes as compared with resting is given in the table below:

Kind of Activity	Total Number of Tests	Average Per Cent above Resting
Resting (100 per cent)	36	
Washing clothes by hand	25	191
Rinsing clothes	21	161
Wringing clothes with hand-power wringer	7	197
Wringing clothes by hand	23	138
Drying clothes in extractor	21	125
Wringing clothes with electric dryer	23	99
Putting up and removing clothes line	7	135
Hanging clothes with basket on floor	21	184
Hanging clothes from utility table	22	118

**Decrease in Output an Indication of Fatigue.** Some people believe that the most practical and useful index of fatigue is its effect upon

<sup>7</sup> A. Durig, "Die Ermüdung im Praktischen Betrieb," Atzler's *Körper und Arbeit*. Leipzig: Thieme, 1927.

<sup>8</sup> E. P. Cathcart, "The Physique of Women in Industry," Industrial Fatigue Research Board, *Report* 44, 1927.

<sup>9</sup> State College of Washington Agricultural Experiment Station, *Bulletin* 282, "The Human Energy Cost of Certain Household Tasks," p. 13. See also *Bulletin* 317, "Time and Cost Evaluation of Home Laundering," 1935.



the quantity and the quality of the individual's work; that fatigue can be measured in terms of reduced output resulting from work. However, one cannot say definitely that a reduction in output results from fatigue. That a person turns out less work during the last hour of the day may, of course, be due to the fact that he is tired. It may also be due to the fact that he has lost interest in the job, because he is worried about some personal problem, or simply because he believes he has already done a day's work.

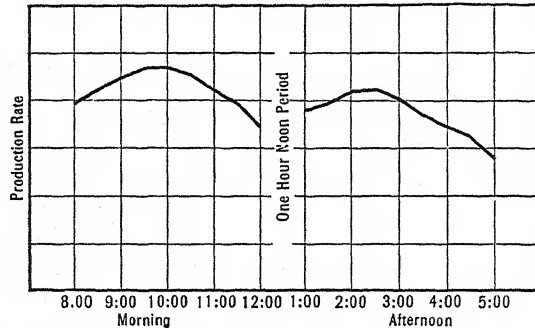


FIG. 107. Typical daily production curve for an individual engaged in very heavy muscular work.

The amount of work done per unit of time may be shown by means of a production curve, sometimes called an output curve or a work curve. It is not improbable that the production curve for *very heavy* manual work might take the shape shown in Fig. 107. Some people interpret this curve in the following way. The upward slope of the curve indicates a "warming up" period in the morning. This is followed by an increase in output until the middle of the morning, when a falling off in production occurs, possibly due to the fatigue of the worker. The curve for the afternoon is similar in shape to that for the forenoon, except that it falls off more rapidly towards the end of the day.

Much work in industry today is light and requires little physical exertion on the part of the operator. The production curve shown in Fig. 108 seems to be typical for such work, there being a fairly uniform output throughout the day. The operator has such a reserve of energy and the physical requirements of the task are so small that it is entirely possible for the operator to maintain a steady output for the entire day. In fact, it is not uncommon to find an operator actually increasing his speed during the last hour of the day when a delay has



existed early in the day causing him to fall behind, or when a rush job has been put into production.<sup>10</sup>

There are many factors which affect the amount of work that an individual will do in a day and the extent of the physical fatigue that will result from this work. With a given set of working conditions and equipment, the amount of work done in a day will depend upon the ability of the worker, and the speed at which he works. This latter factor depends directly upon the individual's inclination or his "will to work," which itself is affected by many things. The fatigue

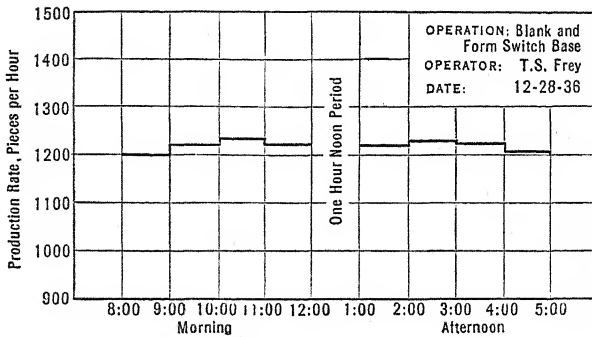


FIG. 108. Production curve for blanking and forming switch base on No. 21 Bliss press.

resulting from a given level of activity will depend upon such factors as (1) hours of work, i.e., the length of the working day and the weekly working hours, (2) the number, location, and length of rest periods, (3) working conditions, such as lighting, heating, ventilation, and noise, and (4) the work itself.

**Hours of Work.** The findings of the Health of Munition Workers Committee organized in Great Britain in 1915 gave impetus to the movement for decreasing the length of the working day. At that time the 12- to 15-hour day was common. The reports of this committee and of many other investigations made since that time indicate the economy of shorter working hours. There is evidence to show that on most work, except in operations whose output depends mainly upon the speed of the machine, the reduction of the length of the working day to 8 hours results in an increase in hourly and daily output.<sup>11</sup>

<sup>10</sup> A. G. Anderson, "A Study of Human Fatigue in Industry," an abstract of a thesis, pp. 20-22, University of Illinois, 1931.

<sup>11</sup> H. M. Vernon, "Industrial Fatigue and Efficiency," George Routledge & Sons, London, 1921. Also, "Two Studies on Hours of Work," Industrial Fatigue Research Board, Report 47, 1928.



Since, in this country, the 8-hour day and the 5-day week are now in effect, there seems to be little to be gained from a further reduction in the length of the working day in so far as preventing physical fatigue is concerned. When increased demands for output cannot be met with an 8-hour day, the possibility of two 8-hour shifts per day offers a practical way out. This also tends to reduce the overhead costs of operating the plant since the overhead expenses would be distributed over a larger number of units.

**Rest Periods.** Rest is a physical necessity during heavy work, and whether "official" rest periods are allowed by the management or not workers will rest during a considerable part of the day. Vernon found that on heavy work, men rested one-half to one-fourth of the working time.<sup>12</sup> Taylor, in his classic experiment of handling pig iron, increased the output from 12½ tons to 47 tons per day mainly by requiring that the workmen rest 57 per cent of the time and work but 43 per cent of the time.<sup>13</sup> Several investigations of workers on medium heavy muscular work and on an 8-hour day show that the worker cannot give his maximum output unless he rests approximately 15 per cent of the time during the working day.<sup>14</sup> It should be noted that these examples are taken from heavy and medium heavy work and that much work in industry today is very light and requires little physical exertion on the part of the operator.

In many kinds of work, both heavy and light, rest periods are desirable for the following reasons: (1) rest periods increase the amount of work done in a day, (2) the workers like the rest periods, (3) rest periods decrease the variability in the rate of working and tend to encourage the operator to maintain a level of performance nearer his maximum output, (4) rest periods reduce physical fatigue, and (5) they reduce the amount of personal time taken during the working hours.

Rest periods are usually placed in the middle of the morning and the middle of the afternoon and range in length from 5 to 15 minutes, 7 to 10 minutes being most common. The proper number of rest periods and the proper length of each will depend upon the nature of the work and can be determined most satisfactorily by experiment.

<sup>12</sup> H. M. Vernon and others, "Rest Pauses in Heavy and Moderately Heavy Industrial Work," Industrial Fatigue Research Board, *Report* 41, p. 20, 1927.

<sup>13</sup> F. W. Taylor, "The Principles of Scientific Management," p. 57, Harper & Bros., New York, 1911.

<sup>14</sup> G. H. Shepard, "Effect of Rest Periods on Production," *Personnel Journal*, Vol. 7, No. 3, p. 186, August, 1928.



A study of the output curve may indicate the time at which output reaches its maximum, which is the point where a rest period should be introduced. Rest periods are particularly effective in heavy manual work, in operations that require close attention and concentration, such as fine inspection work, and in work that is highly repetitive and monotonous.

Tests show that definite rest periods sanctioned by the management have a far greater recuperative effect than those which must be taken surreptitiously. Whether the rest is in the form of "soldiering" or whether it is enforced because of lack of materials, such hit or miss rests may have as little as one-fifth the value of prescribed rests in relieving fatigue.<sup>15</sup>

**Lighting, Heating, and Ventilation.** Lighting, heating, and ventilation have a definite effect upon the physical comfort, mental attitude, output, and fatigue of the worker. Working conditions should be so adjusted as to make the shop and office a comfortable place in which to work. The requirements for proper illumination, heating, and ventilation are well understood, and equipment that will supply comfortable physical conditions for work is now available.

Of these three factors, illumination is perhaps most inadequately provided in most plants. Where the work is of such a nature that visual perception is required for its satisfactory performance, the output is invariably increased when adequate illumination is provided. Inspection operations such as those described on pages 264 to 270 are examples of work of this nature.

**Noise and Vibration.** Although noise is annoying to practically everyone, adaptation to such conditions is readily made by most people, and the psychological and physiological effects of noise are not so serious as many people believe.<sup>16</sup> Viteles draws the following conclusions from his study of noise:

1. No experimental evidence is available to show that automatic performance is adversely affected by noise or by vibration.
2. Nevertheless, except with certain "meaningful" noises, there is a wide agreement that both noise and vibration are "disagreeable" or "uncomfortable" accompaniments of work.
3. A continuous noisy background often appears to have an initial stimulating effect, and this taken together with (2) appears to indicate that the noise should be regarded as an adverse condition which is met by an unwitting increase of effort.

<sup>15</sup> H. M. Vernon, Industrial Fatigue Research Board, *Report* 41, p. 21, 1927.

<sup>16</sup> K. G. Pollock and others, "Two Studies in the Psychological Effects of Noise," Industrial Health Research Board, *Report* 65, p. 30, 1932.



4. With constructive work involving mental effort fairly consistent slight deterioration is observed, particularly in continued effort. Although so far as the experiments go, the deterioration is barely or only just statistically significant, it may be "psychologically" significant. The consistency of the small deterioration seems to point to this.
5. Discontinuous noise is more subjectively disturbing than continuous noise; "meaningful" noise may be more or less disturbing than "unmeaning" noise according as it is interesting or familiar.<sup>17</sup>

Since noise and vibration are annoying they are undesirable and should be reduced or eliminated in so far as possible. Stamping, cutting, and press work are often segregated in one part of the factory so that the remainder of the plant may be kept relatively free from noise. Where large numbers of employees are affected and where the work requires a high degree of concentration or attention, it may be economical to reduce the noise by covering the ceilings and walls with acousticon as is done in many places.<sup>18</sup>

**Effect of Mental Attitude on Fatigue.** Fatigue is by no means the simple, easily defined thing that many would have us believe it to be. Cathcart,<sup>19</sup> Dill,<sup>20</sup> and Mayo,<sup>21</sup> all of whom have written very clearly on this subject, point out the many-sided nature of fatigue.

A carefully conducted study of fatigue lasting over a period of several years, made of factory operators on regular production work at the Western Electric Company, showed that the mental attitude of the workers was by far the most important factor governing the employee's efficiency.

Specific conclusions <sup>22</sup> relating to this point are:

1. The amount of sleep has a slight but significant effect upon individual performance.
2. A distinct relationship is apparent between the emotional status or home conditions of the girls and their performance.

<sup>17</sup> M. S. Viteles, "Industrial Psychology," p. 510, W. W. Norton & Co., Inc., New York, 1932.

<sup>18</sup> B. E. Lies and Marie P. Sealy, "Motion Study Principles and Their Application in a Department Store," *Transaction of the A.S.M.E.*, Vol. 50, No. 29, Jan-50-17A, p. 21, 1928.

<sup>19</sup> E. P. Cathcart, "The Human Fatigue in Industry," Oxford University Press, London, 1928.

<sup>20</sup> D. B. Dill, "Fatigue and Work Efficiency," *Personnel Journal*, Vol. 9, No. 4, pp. 112-116, May, 1933, American Management Association.

<sup>21</sup> E. Mayo, "The Human Problems of an Industrial Civilization," Macmillan Co., New York, 1933.

<sup>22</sup> G. A. Pennock, "Industrial Research at Hawthorne, an Experimental Investigation of Rest Periods, Working Conditions, and Other Influences," *Personnel Journal*, Vol. 8, No. 5, p. 311, February, 1930.



3. Total daily productivity is increased by rest periods, and not decreased.
4. Outside influences tend to create either a buoyant or a depressed spirit which is reflected in production.
5. The mental attitude of the operator toward the supervisor and working and home conditions is probably the biggest single factor governing the employee's efficiency.

Additional statements bearing on this point were selected by Mayo<sup>23</sup> from reports of the experiment made at Hawthorne. Some of these are given here.

There has been a continual upward trend in output which has been independent of the changes in rest pauses. This upward trend has continued too long to be ascribed to an initial stimulus from the novelty of starting a special study.

There has been an important increase in contentment among the girls working under test-room conditions.

There has been a decrease in absences of about 80 per cent among the girls since entering the test-room group. Test-room operators have had approximately one-third as many sick absences as the regular department during the last six months.

Observations of operators in the relay assembly test room indicate that their health is being maintained or improved and that they are working within their capacity. . . .

Important factors in the production of a better mental attitude and greater enjoyment of work have been the greater freedom, less strict supervision and the opportunity to vary from a fixed pace without reprimand from a gang boss.

The operators have no clear idea as to why they are able to produce more in the test room; but as shown in the replies to questionnaires . . . there is the feeling that better output is in some way related to the distinctly pleasanter, freer, and happier working conditions.

**Improving the Method of Doing the Work.** It has been estimated that 25 to 50 per cent of the manual work done in our shops, offices, factories, and homes is unnecessary—that the work might be done in a much better way, producing the same output with less expenditure of energy on the part of the workers. The industrial engineer has, in the past, played an important part in increasing labor effectiveness and his opportunities in this field are greater today than ever before. In performing his task, motion and time study serves as one of his most valuable tools.

It so happens that in finding a better way of doing work, the task is nearly always made easier and more satisfying for the worker because the improved way is a logical and convenient way, permitting smooth, natural, rhythmical motions.

<sup>23</sup> E. Mayo, *op. cit.*, p. 67.



The next three chapters give principles and rules which have been found useful in improving methods of doing work. These twenty-two principles have the common purpose of suggesting ways of using the capacities of the human body most effectively—indicating methods that permit the greatest economy of motion.



# PRINCIPLES OF MOTION ECONOMY

## A CHECK SHEET FOR MOTION ECONOMY AND FATIGUE REDUCTION

These twenty-two rules or principles of motion economy may be profitably applied to shop and office work alike. Although not all are applicable to every operation, they do form a basis or a code for improving the efficiency and reducing fatigue in manual work.

<i>Use of the Human Body</i>	<i>Arrangement of the Work Place</i>	<i>Design of Tools and Equipment</i>
1. The two hands should begin as well as complete their motions at the same time. (Page 193.)	9. There should be a definite and fixed place for all tools and materials. (Page 229.)	17. The hands should be relieved of all work that can be done more advantageously by a jig, fixture, or a foot-operated device. (Page 280.)
2. The two hands should not be idle at the same time except during rest periods. (Page 193.)	10. Tools, materials, and controls should be located close in and directly in front of the operator. (Page 231.)	18. Two or more tools should be combined wherever possible. (Page 293.)
3. Motions of the arms should be made in opposite and symmetrical directions, and should be made simultaneously. (Page 193.)	11. Gravity feed bins and containers should be used to deliver material close to the point of use. (Page 245.)	19. Tools and materials should be pre-positioned whenever possible. (Page 295.)
4. Hand motions should be confined to the lowest classification with which it is possible to perform the work satisfactorily. (Page 216.)	12. "Drop deliveries" should be used whenever possible. (Page 251.)	20. Where each finger performs some specific movement, such as in typewriting, the load should be distributed in accordance with the inherent capacities of the fingers. (Page 298.)
5. Momentum should be employed to assist the worker wherever possible, and it should be reduced to a minimum if it must be overcome by muscular effort. (Page 218.)	13. Materials and tools should be located to permit the best sequence of motions. (Page 253.)	21. Handles such as those used on cranks and large screwdrivers should be designed to permit as much of the surface of the hand to come in contact with the handle as possible. This is particularly true when considerable force is exerted in using the handle. For light assembly work the screwdriver handle should be so shaped that it is smaller at the bottom than at the top. (Page 301.)
6. Smooth continuous motions of the hands are preferable to zigzag motions or straight-line motions involving sudden and sharp changes in direction. (Page 219.)	14. Provisions should be made for adequate conditions for seeing. Good illumination is the first requirement for satisfactory visual perception. (Page 261.)	22. Levers, crossbars, and hand wheels should be located in such positions that the operator can manipulate them with the least change in body position and with the greatest mechanical advantage. (Page 305.)
7. Ballistic movements are faster, easier, and more accurate than restricted (fixation) or "controlled" movements. (Page 224.)	15. The height of the work place and the chair should preferably be arranged so that alternate sitting and standing at work are easily possible. (Page 271.)	
8. Rhythm is essential to the smooth and automatic performance of an operation, and the work should be arranged to permit easy and natural rhythm wherever possible. (Page 226.)	16. A chair of the type and height to permit good posture should be provided for every worker. (Page 276.)	



## CHAPTER 15

### PRINCIPLES OF MOTION ECONOMY AS RELATED TO THE USE OF THE HUMAN BODY

Although the phrase "principles of motion economy" is used very frequently in engineering literature, it seems impossible to find a satisfactory statement of these principles in sufficient detail to be of value to those who are not expert in the field.

On several occasions Gilbreth listed certain "rules for motion economy and efficiency"<sup>1</sup> which govern hand motions, and from time to time other investigators in this field have added to this list.

Additional research which will enlarge our knowledge of the inherent capacities of the various members of the human body is greatly needed. There is much yet to be done in determining the fundamental laws which permit the maximum amount of productive effort with a minimum of fatigue. Although the material in this chapter is discussed under the heading "principles of motion economy," it might perhaps have been more accurately designated as "some rules for motion economy and fatigue reduction."

In attempting to collect and codify the authentic information which is already available for use as a guide in determining methods of greatest economy, one is confronted with a number of difficulties. If general principles are stated they are likely to be abstract and of little practical use; whereas if narrower rules with specific illustrations are presented they may lack universality of application. In the past it has been customary to make general statements of the principles without including additional information or practical applications. This

<sup>1</sup>F. B. and L. M. Gilbreth, "A Fourth Dimension for Measuring Skill for Obtaining the One Best Way," *Society of Industrial Engineering Bulletin*, Vol. 5, No. 11, November, 1923. Gilbreth gave sixteen rules for motion economy in the above article, and these rules have been listed in a more recent publication: W. J. Donald (Ed.), "Handbook of Business Administration," Chapter 8, p. 640, McGraw-Hill Book Co., New York, 1931. See also: A. H. Mogensen, "Common Sense Applied to Motion and Time Study," pp. 98-99, McGraw-Hill Book Co., 1932, and F. B. Gilbreth, "Motion Study," pp. 10-85, Van Nostrand Co., New York, 1911.



has been very unsatisfactory and has retarded the use of motion and time study.

It is the purpose of this and the following two chapters to interpret by means of specific illustrations some of the general rules or principles of motion economy which have been and are now being successfully used in industry. All the principles presented in these chapters are not of equal importance, nor does this discussion include all the factors which enter into the determination of better methods for doing work. These principles do, however, form a basis—a code, or a body of rules—which, if applied by one trained in the technique of motion study, will make it possible to increase greatly the output of manual labor with a minimum of fatigue.

These principles will be presented under the following three subdivisions:

- I. Principles of motion economy as related to the use of the human body.
- II. Principles of motion economy as related to the arrangement of the work place.
- III. Principles of motion economy as related to the design of tools and equipment.

### Principles of Motion Economy as Related to the Use of the Human Body

**1. THE TWO HANDS SHOULD BEGIN AS WELL AS COMPLETE THEIR MOTIONS AT THE SAME TIME.**

**2. THE TWO HANDS SHOULD NOT BE IDLE AT THE SAME TIME EXCEPT DURING REST PERIODS.**

**3. MOTIONS OF THE ARMS SHOULD BE MADE IN OPPOSITE AND SYMMETRICAL DIRECTIONS AND SHOULD BE MADE SIMULTANEOUSLY.**

These three principles are closely related and can best be considered together.<sup>2</sup> It seems natural for most people to work productively with one hand while holding the object being worked on with the other hand. This is usually undesirable. The two hands should work together, each beginning a motion and completing a motion at the same time. Motions of the two hands should be simultaneous and symmetrical.

<sup>2</sup> These three principles were first stated by F. B. and L. M. Gilbreth, "A Fourth Dimension for Measuring Skill for Obtaining the One Best Way to Do Work," *Society of Industrial Engineering Bulletin*, Vol. 5, No. 11, p. 6, November, 1923.



It is obvious that in many kinds of work more can be accomplished by using both hands than by using one hand. For most people it is advantageous to arrange similar work on the left- and right-hand side of the work place, thus enabling the left and right hands to move together, each performing the same motions. The symmetrical movements of the arms tend to balance each other, reducing the shock and jar on the body and enabling the worker to perform his task with less mental and physical effort. There is apparently less body strain

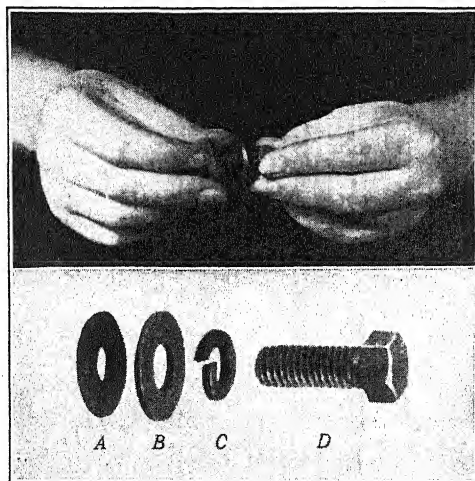


FIG. 109. Bolt and washer assembly: A, special rubber washer; B, flat steel washer; C, lock washer; D,  $\frac{3}{8}$ -inch  $\times$  1-inch bolt.

present when the hands move symmetrically than when they make nonsymmetrical motions because of this matter of balance.

Some examples will be cited to show how better methods were developed through the analysis of the hand motions with which you are now familiar, and through the application of the first three principles of motion economy.

**Bolt and Washer Assembly.** A manufacturing concern uses eight bolts  $\frac{3}{8}$  inch by 1 inch, fitted with three washers each (see Figs. 109 and 110), in the final assembly of one of its products. This operation was facilitated by having the three washers previously assembled onto the bolt; consequently the bolt and washers were assembled by girls at benches in another department.

**Old Method of Assembly.** The bolt and washer assembly was originally made in the following manner. Containers with the bolts, lock washers, steel washers, and rubber washers were arranged on the top



of the bench as shown in Fig. 51 on page 76. The operator reached over to the container of bolts, picked up a bolt with her left hand, and brought it up to position in front of her. Then with the right hand she in turn picked up a lock washer from the container on the bench and placed it on the bolt, then a flat steel washer, and then a rubber washer. This completed the assembly, and with the left hand the operator disposed of it in the container to her left. Figure 79 on page 134 gives

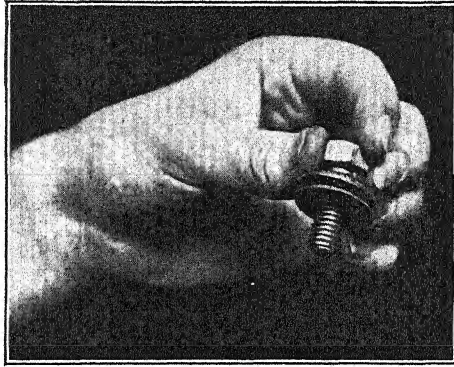


FIG. 110. The hole in the rubber washer is slightly smaller than the outside diameter of the bolt so that when the bolt is forced through the hole it is gripped, thus preventing the washers from falling off of the bolt.

the analysis sheet for this operation, and Fig. 78 shows the pictures of one cycle.

It is readily seen that every one of the three principles named above was violated when the operation was performed in this way although it is the customary method of doing such work. The left hand *held* the bolt during most of the time while the right hand worked productively. The motions of the two hands were neither simultaneous nor symmetrical.

**Improved Method of Assembly.** A simple fixture was made of wood and surrounded by metal bins of the gravity feed type as shown in Figs. 111, 112, and 113. The bins containing the washers are arranged in duplicate so that both hands can move simultaneously, assembling washers for two bolts at the same time. As seen from Fig. 111 bins 1 contain the rubber washers, bins 2 the flat steel washers, bins 3 the lock washers, and bin 4, located in the center of the fixture, contains the bolts. The bottom of the bins slope toward the front at a 30-degree angle so that the materials are fed out onto the fixture board by gravity as the parts are used in assembly.



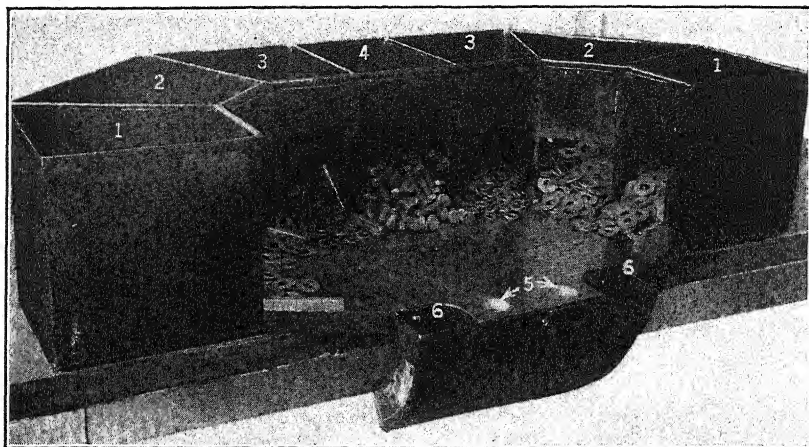


FIG. 111. Bins, fixture, and chute for bolt and washer assembly.

Two countersunk holes or recesses were made in the front of the fixture (see Fig. 112) into which the three washers fitted loosely, the rubber washer on the bottom, the flat steel washer next, and the lock washer on top. A hole slightly larger than the diameter of the bolt went through the fixture as shown in Fig. 112. A metal chute was placed around the front of the wood fixture with openings to the right and to the left of the two recesses so that assembled bolts and washers might be dropped into the top of this chute and carried down under the bench to a container.

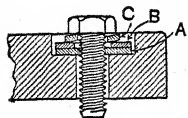


FIG. 112. Enlarged view of recess in wood fixture for assembling bolt and washers: A, rubber washer; B, steel washer; C, lock washer.

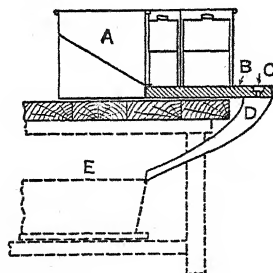


FIG. 113. Cross section of bins showing chute for drop delivery: A, bins with sloping bottom; B, top of fixture; C, counter-sunk holes in top of fixture; D, chute; E, container for finished assemblies.

In assembling the bolt and washers, as the chart in Fig. 81 on page 137 shows, the two hands move simultaneously toward the duplicate bins 1, grasp rubber washers which rest on the wood fixture in front of the bins, and slide the rubber washers into place in the two recesses in the fixture. The two hands, then, in a similar way, slide the steel washers into place on top of the rubber washers, and then the lock washers are slid into place on top of these. Each hand, then, grasps a bolt and slips them through



the washers which are lined up so that the holes are concentric. The hole in the rubber washer is slightly smaller than the outside diameter of the threads on the bolt so that when the bolt is forced through the hole it is gripped and thus permitted, with the three washers, to be withdrawn vertically upward without losing the washers (see Fig. 110). The two hands release the assemblies simultaneously over the metal chute. As the operator begins on the next cycle with the hands in this position, the first and second fingers of each hand are in position to grasp the rubber washer which is almost at the tip of the fingers.

A detailed study of the old and the improved methods of assembling the bolt and washers shows:

Average time required to make one bolt and washer assembly by the old method	0.084 minute
Average time required to make one bolt and washer assembly by the improved method	0.055 minute
Time saved	0.029 minute
Increase in output = 53 per cent <sup>3</sup>	

<sup>3</sup> Sometimes the results of an improved method are expressed in "increase in output in per cent" and sometimes the results are expressed in "time saved in per cent." These two percentages do not mean the same thing. Perhaps the following computations may serve to clarify this point:

#### Increase in Output in Per Cent

$$\frac{\left[ \begin{array}{l} \text{Pieces produced} \\ \text{per minute using} \\ \text{new method} \end{array} \right] - \left[ \begin{array}{l} \text{Pieces produced} \\ \text{per minute using} \\ \text{old method} \end{array} \right]}{\left[ \begin{array}{l} \text{Pieces produced per minute} \\ \text{using the old method} \end{array} \right]} \times 100 = [\text{Increase in output in per cent}]$$

*Example:*

$$\begin{aligned} \text{Time for assembly, old method} &= 0.084 \text{ minute} \\ \text{Number of assemblies per minute, old method} &= 1 \div 0.084 = 11.9 \\ \text{Time per assembly, new method} &= 0.055 \text{ minute} \\ \text{Number of assemblies per minute, new method} &= 1 \div 0.055 = 18.2 \\ \frac{18.2 - 11.9}{11.9} \times 100 &= 53 \text{ per cent increase in output} \end{aligned}$$

#### Savings in Time in Per Cent

$$\frac{\left[ \begin{array}{l} \text{Time per piece} \\ \text{using old method} \end{array} \right] - \left[ \begin{array}{l} \text{Time per piece} \\ \text{using new method} \end{array} \right]}{\left[ \begin{array}{l} \text{Time per piece using the old method} \end{array} \right]} \times 100 = [\text{Savings in time in per cent}]$$

*Example:*

$$\begin{aligned} \text{Time per piece, old method} &= 0.084 \text{ minute} \\ \text{Time per piece, improved method} &= 0.055 \text{ minute} \\ \frac{0.084 - 0.055}{0.084} \times 100 &= 35 \text{ per cent savings in time} \end{aligned}$$



The improved method as opposed to the old method of assembling the bolt and washers conforms to each of the three principles of motion economy already mentioned. The two hands begin and end their motions at the same instant, and they move simultaneously in opposite directions. There is no idle time, and neither hand is used as a "vise" for holding material while the other one does the work, as under the old method.

**Filling Mailing Envelope with Advertising Material.** This operation consisted of inserting four sheets of advertising material in a



FIG. 114. Arrangement of work place—old method. Filling mailing envelope with four sheets of advertising material.

mailing envelope and tucking in the envelope flap. The job consisted of picking up the sheets one at a time with the right hand, transferring them to the left hand, jogging them, and then inserting them in the envelope. (See Fig. 114.) It is obvious that the *left* hand was idle part of the time, held the sheets part of the time, and worked in an inefficient manner during the rest of the cycle. Also, the *right* hand was idle part of the time.

**Improved Method.** Two small triangular pieces were made from cardboard and tape and fastened to flat sheets of cardboard. (See Fig. 115.) The advertising material was stacked against the two sides of the triangular pieces which served as fixtures enabling the operator to pick up two sheets at a time with each hand. Rubber



finger stalls facilitated the grasping. Since the sheets of the particular size shown in Fig. 116 were mailed out at frequent intervals, the work place to handle this job was set up permanently. Triangular wood blocks are shown at *A*. The operation now consists of grasping two sheets of paper at a time with each hand, drawing them together, jogging them on block *B* (see Fig. 116), and inserting them in the envelope.

When the operator used the old method of filling envelopes, picking up the sheets one at a time, her production was 350 per hour. How-

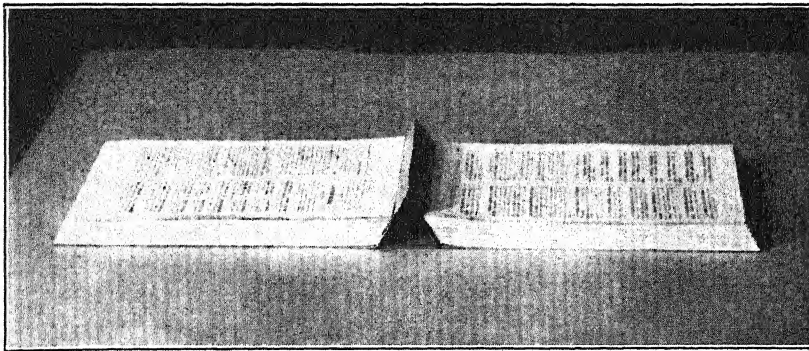


FIG. 115. Temporary fixture for assembling two sheets of advertising material.

ever, using the improved work place layout and the better method, she was able to fill 750 envelopes per hour. The new method is so much easier than the old that she has more than doubled her output.

**Folding Paper Cartons.** Frankfurters are usually packed in cardboard cartons for shipment to the retail meat market. The cartons are delivered to the packing house in flat bundles, and these flat cartons must be formed and the end flaps folded over and locked together before they can be filled with frankfurters. A cover slightly larger than the bottom is placed over the filled carton bottom, telescope fashion. (See Fig. 117.) The shape and design of the cover and bottom of the carton are alike, that is, both the cover and the bottom are folded the same way.

**Old Method.** The operator walked 10 feet, got bundle of fifty carton "flats," and carried them to carton-folding table. Using both hands, the operator grasped a group of eight flat cartons, broke all seams or scored lines to facilitate forming, and placed flats on table with ends toward her. She then grasped the sides of the carton flap and simultaneously bent bottom and side flaps toward center of car-



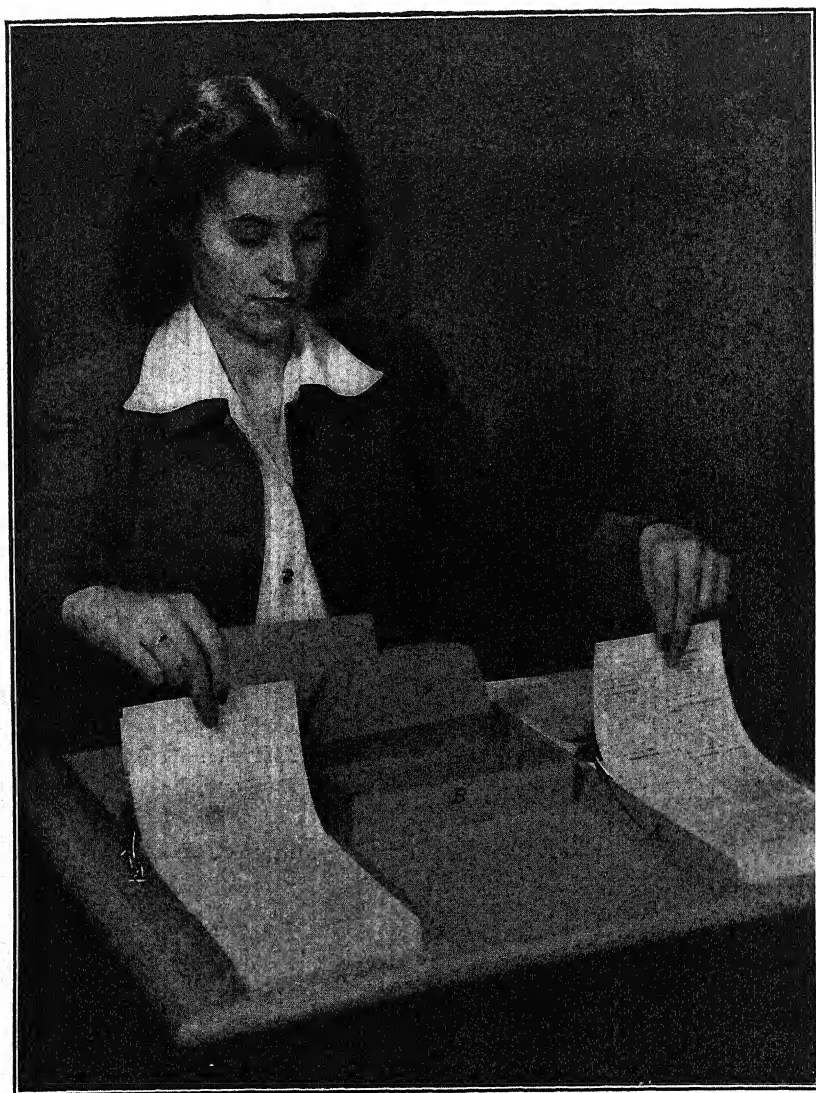


FIG. 116. Arrangement of work place—improved method. Filling mailing envelope with four sheets of advertising material. Since sheets of this particular size were sent out at frequent intervals, the work place shown above was set up permanently. A. Triangular blocks. B. Block on which sheets are jogged.



ton. (See Fig. 118.) Holding the left side flap in position, she inserted the tongue of the right flap into retaining groove of left flap. She then pushed the partly formed carton forward approximately 4 inches to nest. The above procedure was repeated until four cartons were folded at one end.

The operator took the group of partly formed cartons from position on table and turned them end for end so the unfolded ends were toward her. The operator then repeated the folding operation on the second end of the carton flat and placed completely formed carton on the conveyor to be filled with frankfurters.

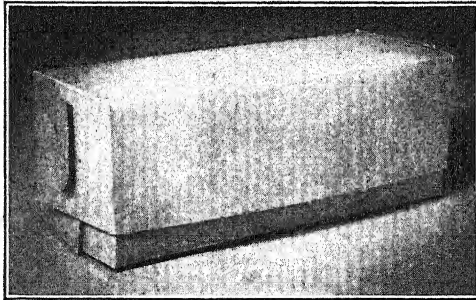


FIG. 117. Carton for packing frankfurters.

**Improved Method.** A simple wood fixture, as shown in Fig. 119, was designed and built.<sup>4</sup> Bundles of flat cartons are now delivered by truck near packing table. The operator gets bundle of fifty flats, carries them to the table, and places them in holder *A* in Fig. 119. With her left hand she reaches to lower end of pile of carton flats, grasps end of middle flap, brings flap to position over forming fixture *B* in Fig. 119. With the right hand she disposes of previously formed carton to conveyor. Then with her right hand she grasps middle flap on right end of carton, which is already positioned in the fixture. Holding both middle end flaps, one in each hand, she bends flaps upward and pushes carton into fixture. The fixture forces rear side flap up 90 degrees, folds two rear end flaps forward 90 degrees, and folds front side and end flaps up approximately 45 degrees. With both hands simultaneously, the operator then reaches to front end flaps, folds end flaps to rear and toward center of carton until end of tongues on front flaps are inside notches of rear end flaps. While holding end flaps in position with fingers, the operator reaches with

<sup>4</sup> Improved method developed by Eugene J. Smith.



thumbs to front corners of carton, pushes front of carton to rear in order to lock tongues of front end flaps into notches of rear end flaps, and thus completes forming carton. The operator then disposes of finished carton onto conveyor.

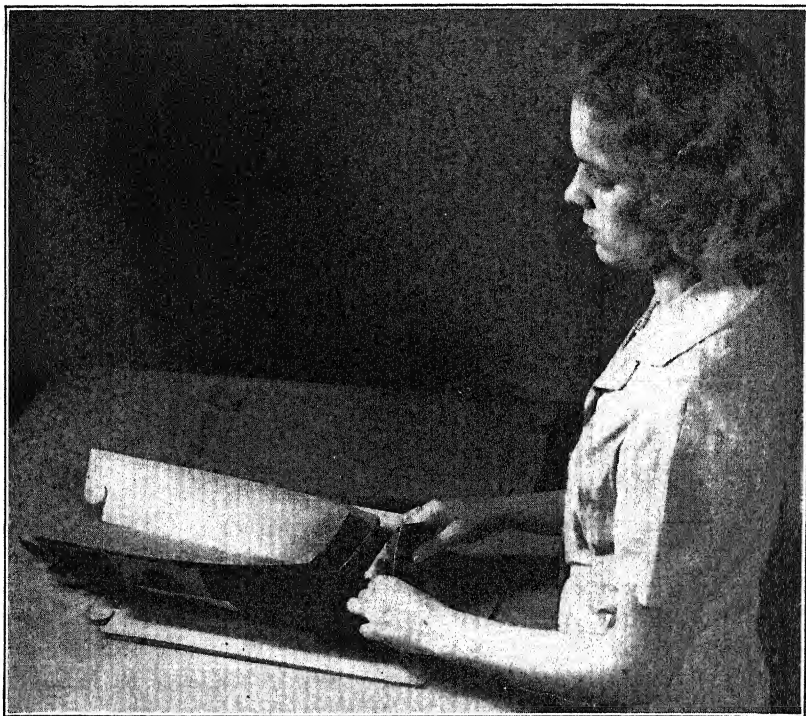


FIG. 118. Old method of folding cartons. Left hand holds one carton flap while right hand locks the other flap to the first.

*Results.* The improved method enabled the operator to double her output. The fixture cost approximately \$10.00 to make. The improved method was superior to the old method for two reasons: (1) elimination of the operation of breaking "seams" or scored lines of fold on carton flats before forming; (2) elimination of holding one flap in position with one hand while assembling the second flap with the other hand.

**Nonsymmetrical Motions.** Frequently the nature of the work prevents the operator from moving his arms simultaneously in opposite and symmetrical directions. When this is the case it may be that the work can be arranged so that the operator can move his arms simul-



taneously in directions perpendicular to each other. An example of this type of movement is shown in Fig. 120. The operation is wrapping and boxing electric switches. The old method was to place the product to be wrapped on one end of a sheet of wrapping paper and



FIG. 119. Improved method of folding cartons. Fixture aids in forming carton and holds it while both hands lock the flaps. Flaps on both ends of carton are assembled at the same time. Operator doubled her output.

then by a folding and rolling process to finish the operation. The product was then placed in a fiber box and the lid was put on. This method of wrapping and boxing was wasteful of time and effort, as well as of paper.

In the improved method two narrow strips of paper are drawn from supply boxes at *A* and *B* (Fig. 120) across the top of the fiber box by perpendicular motions of the two arms. The switch is then placed on top of the paper and pushed down into the box, both ends of the paper being folded over the switch with simultaneous motions of the two hands. Finally the lid is placed on the box. Incidentally the new method of wrapping and boxing the electric switch requires 40 per cent less time than the old method.



There is a certain balance and ease of muscular control to these motions performed at right angles which make them definitely superior to motions of the arms in the same direction. However, they are not so easy as simultaneous motions of the arms in opposite directions and should be used only when the former motions are impossible.

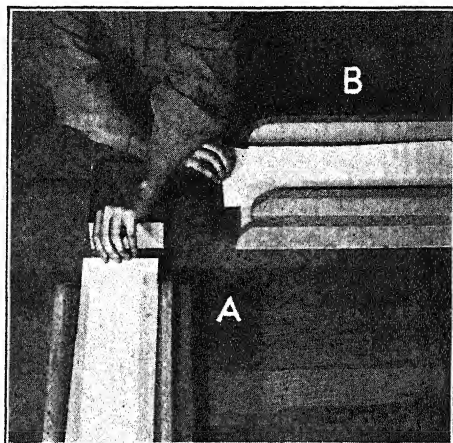


FIG. 120. Simultaneous motions of the arms perpendicular to each other. The operation is that of wrapping and boxing electric switches.

**Eye Movements.** Although some kinds of work can be performed with little or no eye direction, where visual perception is required, it is essential that the task be so arranged that the eyes can direct the work effectively, that is, the work place should be so laid out that the eye fixations are as few and as close together as possible.

Figure 121 shows head, eye, and hand motions of the operator performing a simple assembly operation. Small steel washers enameled green on one side and black on the other were to be assembled with green side up in the fixture directly in front of the operator. Duplicate bins containing the washers were located on either side of the fixture. As the figure shows, it was necessary for the operator to look first to the right and then to the left before grasping the washers. The first strip of film in Fig. 121 shows the operator looking to her right preparatory to grasping a washer from the bin at her right. The second and third strips of film show her looking to her left and grasping a washer from the bin at her left; and the fourth strip of film shows the two hands moving simultaneously carrying washers





FIG. 121. Print of motion-picture film showing eye and hand motions of the operator assembling small parts.



to the fixture. The 36 consecutive frames of film reproduced in Fig. 121 were made at 1000 exposures per minute.

The distance that the eyes and the hands have to move and the nature of the operation will determine whether the hands must wait for the eyes, thus increasing the time to perform the task. In the

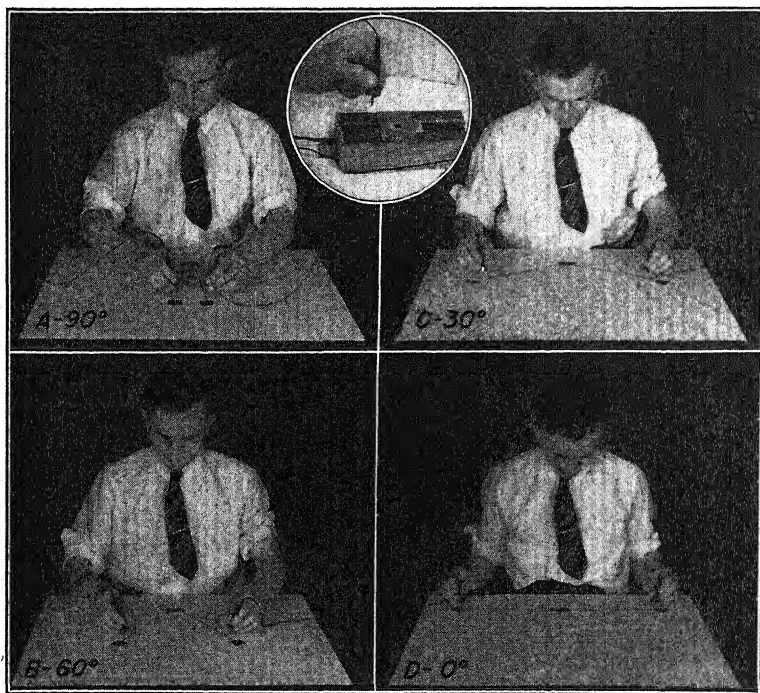


FIG. 122. Arrangement of the work place for study requiring visual direction of the hands. The angle which the motion path of each hand made with the plane of the front of the operator's body is shown in each of the four photographs. The circular insert shows a close-up of the operator inserting an electrode into the hole in an uncovered unit.

above case had the containers been placed directly in front of the operator, the head movements would have been eliminated entirely and the eye movements would have been greatly reduced.

**Arrangement of the Work Place.** In Figs. 122 and 123 are shown the results of an investigation<sup>5</sup> made by M. E. Mundel to evaluate the effect of the angle which the motion paths of the operator's hands made with the plane of the front of the worker's body upon the effi-

<sup>5</sup> University of Iowa Studies in Engineering, *Bulletin* 17, 1939.



ciency with which the worker moved his hands away from and towards his body in a simultaneous, symmetrical fashion.

In the first part of the study the operator was seated at a table (see Fig. 122) and simultaneously carried with each hand an electrode



FIG. 123. Arrangement of the work place for study not requiring visual direction of the hands. Only one arrangement is shown—the motion path of each of the operator's hands makes an angle of 60 degrees with the plane of the front of the operator's body.

about the size of a pencil back and forth between points on the work place. These points were located symmetrically for the two hands, and the operator inserted the electrodes simultaneously into  $\frac{3}{8}$ -inch holes in metal plates on the work place surface at the terminal

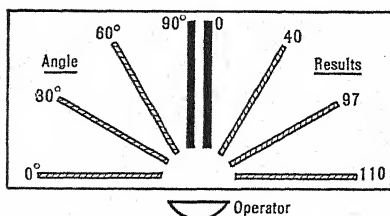


FIG. 124. Results of study requiring visual direction of the hands.

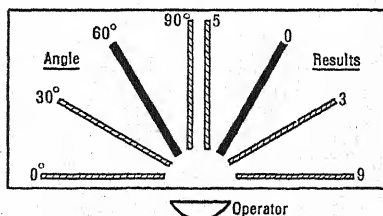


FIG. 125. Results of study not requiring visual direction of the hands.

points. Two sets of holes located 10 inches apart required 10-inch motions of each of the two hands.

In the second part of the study the operator moved small slides (wood blocks) simultaneously back and forth on smooth wood bars (see Fig. 123). Stops at either end of the bar permitted the operator



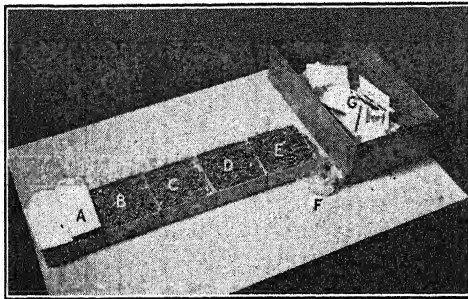


FIG. 126. Layout of work place for packaging wood screws—old method. A. Envelopes with gummed flap; B.  $\frac{1}{2}$ -inch No. 5 wood screws; C.  $\frac{3}{4}$ -inch No. 5 wood screws; D. 1-inch No. 7 wood screws; E. 1-inch No. 9 wood screws; F. Moistener; G. Filled envelopes.

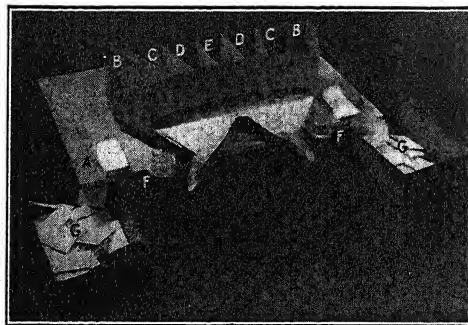


FIG. 127. Layout of work place for packaging wood screws—first improvement.

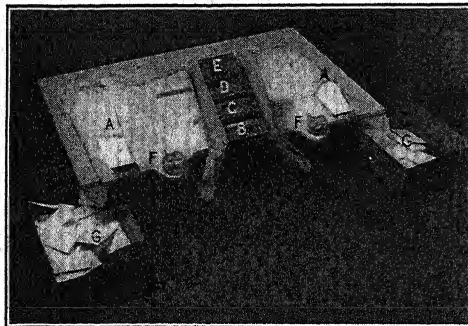


FIG. 128. Layout of work place for packaging wood screws—second improvement.

to make 10-inch movements of the blocks without conscious direction. The time required to make this back and forth motion with the two hands was measured in thousandths of a second.

In the first case visual direction was required to perform the task; in the second case the eyes were not used. The results of this investigation showed that the 90-degree position was the best when visual direction was required, whereas the 60-degree angle required the least time when the eyes were not needed to direct the hands. (See Figs. 124 and 125.)

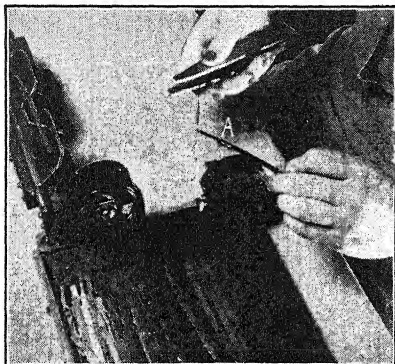
#### Packaging Small Parts.

A study<sup>6</sup> of various methods of packaging small parts was made in order to find the most effective one. The operation consisted of placing seven small screws of four different sizes in a small envelope and then sealing it. Figure 126 shows the layout of the work place for the old method. By arranging the materials as shown in Fig. 127 a substantial saving in time resulted. However, a second improvement was

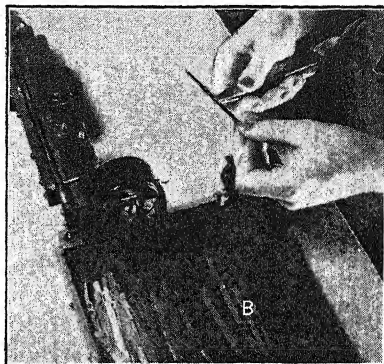
<sup>6</sup> This study was made by Bert H. Norem and John M. MacKenzie.



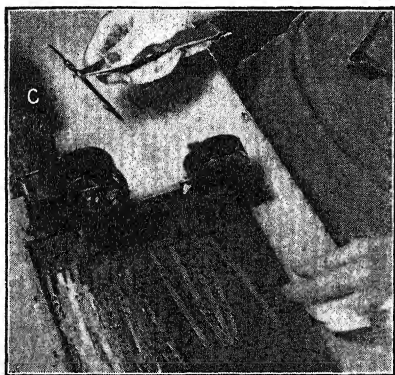
made later, as shown in Fig. 128, which further reduced the time for the operation. Some visual direction was required in this



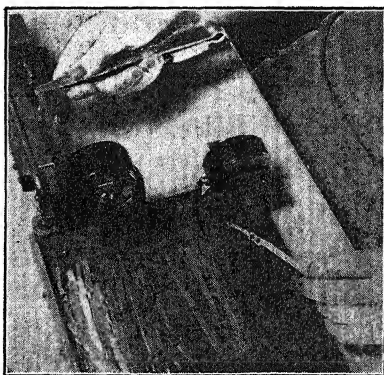
I. As the tweezers start to open when releasing the part in the die, the eyes shift to the part in the left hand to direct the tweezers—grasping of the next part. First fixation at A.



II. Before the right hand releases the part in the tweezers, the eyes shift to the supply tray to select the next part. Second fixation at B.



III. After the left hand is sufficiently well directed towards the part on the supply tray, the eyes shift to the die to direct the right hand in locating the part over the pilot pins. Third fixation at C.



IV. The eyes remain fixed on the die until the part is properly located. The part is ejected by a foot pedal as the right reaches for the next part.

FIG. 129. Punch-press operation showing eye fixations and hand motions of a beginner. Three fixations were used per cycle.

operation, and the work place as finally arranged enabled the operator to reduce the extent of the head and eye movements and also to shorten the hand motions. This further illustrates that eye motions should always be considered in determining the best method of doing a task.



**Eye-Hand Coordination.** In a study<sup>7</sup> of the effect of practice on individual motions of a punch-press operation made in the University of Iowa Industrial Engineering Laboratory in cooperation with Western Electric Company, one of the observations was the effect of practice on eye movements.

The operation was the forming of a relay contact bar. The fixture and work-place arrangement shown in Figs. 129 and 130 were designed to duplicate the mechanical movements and hand motions of the actual factory operation.

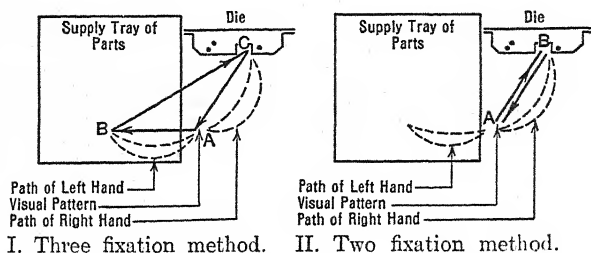


FIG. 130. Punch-press operation. Schematic drawings, showing eye fixations and hand motions.

The eye movements and the hand motions of the beginner, shown in Figs. 129 and 130-I, are as follows:

As the tweezers start to open when releasing the part in the die the eyes shift to the part in the left hand to direct the tweezer-grasping of the next part. The first fixation of the eyes occurs at A in Fig. 129-I.

Before the right hand releases the part into the tweezers, the eyes shift to the supply tray to select the next part. The second fixation occurs at B in Fig. 129-II.

If the left hand is sufficiently well directed towards the part on the supply tray, the eyes shift to the die to direct the right hand in locating the part over the pilot pins. The third fixation occurs at C in Fig. 129-III.

The eyes remain fixed on the die until the part is properly located. The part is ejected by a foot pedal as the right hand reaches for the next part.

However, after 10,000 cycles of practice 56 per cent of the cycles had three fixations while the remaining 44 per cent had two fixations. At first the cycle time averaged 0.0584 minute, and after 10,000 cycles

<sup>7</sup> Ralph M. Barnes, James S. Perkins, and J. M. Juran, "A Study of the Effect of Practice on the Elements of a Factory Operation," University of Iowa Studies in Engineering, *Bulletin* 22, 1940.



of practice the average time was 0.0258 minute. When only two fixations occurred the hand movements were the same, but the eyes did not

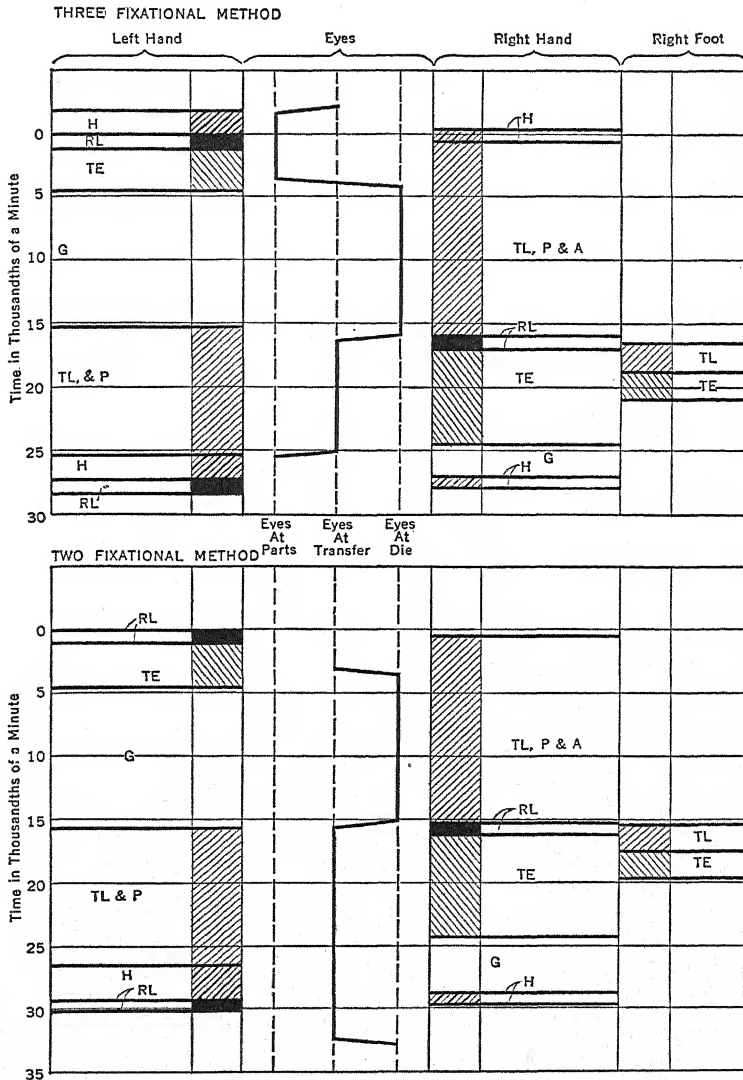


FIG. 131. Eye-hand simo chart of punch-press operation showing the three fixational method and the two fixational method.

fixate on the supply of parts. The eyes would fixate on the part as it was transferred from the left hand to the right hand at A in Fig. 130-II, and then the eyes would move to the fixture to direct in locating the



part over the pilot pins at *B* in Fig. 130-II. Although at first it was necessary to look at the parts in the tray to facilitate the grasping, after practicing a less-defined picture was necessary. It is believed that attention was directed to the parts and to the hand in grasping

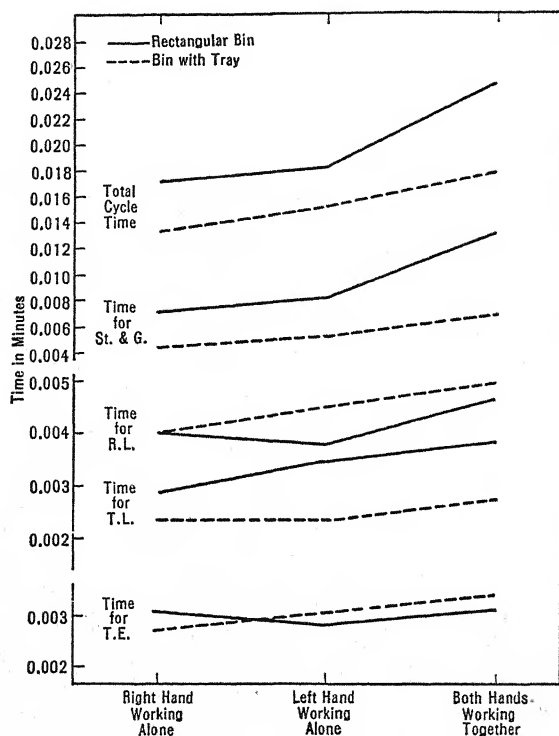


FIG. 132. Curves showing results of study of one- and two-handed work. Averages of the medians selected by total cycle time were used. Results from five male operators working with No. 2 nuts and five who worked with No. 8 nuts have been combined.

them but that it was not essential for the eyes to see the parts so clearly.


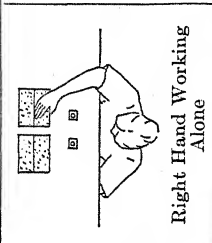
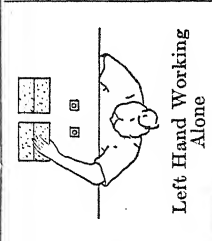
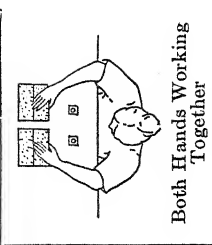
It seems that the better coordination resulting from practice not only enabled the operator to perform each of the motions in less time (although they were not all affected in the same way with practice) but also reduced the number of fixations required.

**One- and Two-Handed Work.** The results of a study<sup>8</sup> of the time to select and grasp, transport, and dispose of machine screw nuts from

<sup>8</sup> University of Iowa Studies in Engineering, *Bulletin* 21, 1940.



TABLE XIV  
STUDY OF ONE- AND TWO-HANDED WORK

	<b>SELECT AND GRASP</b> Nut from bin at A (see figure above).	Time in Minutes Time in Per Cent (Shortest Time = 100%)				Rectangular Bin	Bin with Tray	Rectangular Bin	Bin with Tray		
	Time in Minutes Time in Per Cent (Shortest Time = 100%)	0.00723				100	0.00438	0.00822	114	118	0.00520
	Time in Minutes Time in Per Cent (Shortest Time = 100%)	0.00292				100	0.00235	0.00347	119	100	0.00234
	Time in Minutes Time in Per Cent (Shortest Time = 100%)	0.00403				106	0.00403	0.00380	112	100	0.00453
	Time in Minutes Time in Per Cent (Shortest Time = 100%)	0.00314				111	0.00277	0.00282	100	110	0.00304
<b>TRANSPORT LOADED</b> Carry nut through distance of 5 inches —from A to B.	Time in Minutes Time in Per Cent (Shortest Time = 100%)	0.01730	0.01351	0.01832	0.01510	122	124	0.00308	0.00337		
<b>RELEASE LOAD</b> Drop nut into 1-inch hole in table top at B.	Time in Minutes Time in Per Cent (Shortest Time = 100%)	100	100	0.01351	0.01510	122	124	0.00308	0.00337		
<b>TRANSPORT EMPTY</b> Move hand to bin at A for nut.	Time in Minutes Time in Per Cent (Shortest Time = 100%)	0.01730	0.01351	0.01832	0.01510	122	124	0.00308	0.00337		
<b>TOTAL CYCLE</b>	Time in Minutes Time in Per Cent (Shortest Time = 100%)	0.01730	0.01351	0.01832	0.01510	122	124	0.00308	0.00337		



two types of bins with the right hand alone, with the left hand alone, and with both hands working together are shown in Fig. 132 and Table XIV.

The operation consisted of selecting and grasping machine screw nuts (Nos. 2 and 8) from a bin, carrying them through a distance of 5 inches, and disposing of them in a hole in the table top. The study was made using a rectangular bin and was then repeated using a bin with tray. These bins are shown on page 247. The operator

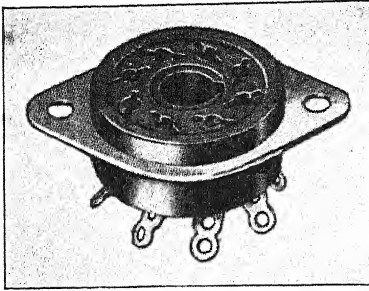


FIG. 133. Radio tube socket—original design.

worked first with the right hand alone, then with the left hand alone, and finally with both hands.

Least time was required for a total cycle when only the right hand was used. A cycle for the left hand required 6 per cent more time with the rectangular bin, and 12 per cent more time with the bin with tray; and a cycle with both hands required 30 to 40 per cent more time.

However, since two cycles were performed simultaneously when the two hands were used, the time chargeable to each cycle was considerably less than when only the right hand was used.

Under the conditions observed in this investigation and with the operators studied, there was considerable evidence to indicate that a good "one-handed" operator was also a good "two-handed" operator, and a relatively poor one-handed operator was also a relatively poor two-handed operator. This suggests that the introduction of two-handed simultaneous work in place of less efficient one-handed work will not inconvenience any one operator very much more than another operator.

**Redesign of Parts to Facilitate Assembly.** In order to avoid microphonics in radio sets, one radio manufacturer uses rubber grommets in mounting certain tube sockets or bases onto the radio frame.

The original method of inserting the rubber grommets into the hole in the tube socket (see Fig. 133) was tedious and difficult. By cutting out a slot in the two sides of the metal base plate (see Fig. 134) it was simple to squeeze the rubber grommet together and insert it through the slot into the hole. Moreover, by mounting the base on a fixture, two grommets, one held in each hand, could be assembled into the holes at the same time.



The time to insert the grommet in each of the two holes in the base using the old method was 142.5 minutes per 100 sockets. The improved method permitted the operator to perform the same operation at the rate of 40 minutes per 100 sockets. The sockets were purchased

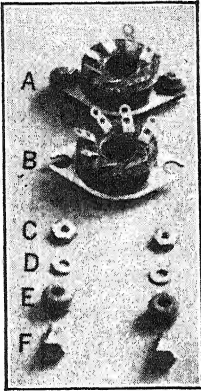


FIG. 134. Radio tube socket—improved design.

- A—Socket assembly
- B—Base showing slots cut out of two sides of metal plate to facilitate assembly of rubber grommets
- C—Nuts
- D—Lock washers
- E—Rubber grommets.
- F—Bolts for mounting socket onto radio base

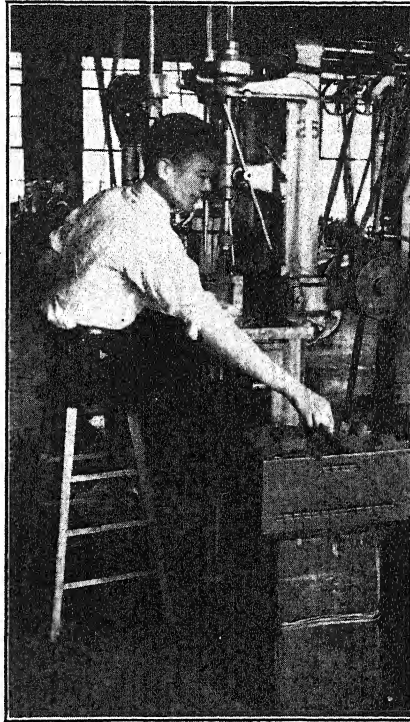


FIG. 135. Drilling and counterboring operation. The material to be drilled is poorly placed resulting in slow, fatiguing work.

by the radio manufacturer, and it was possible to have the supplier furnish the improved design of socket at no extra cost. The only expense involved in making the change in the method was a few dollars for an assembly fixture which was made of wood.

**Jigs and Fixtures.** One of the important things about motion study applications is that usually only simple jigs, fixtures, and special apparatus are needed. Where the number of units to be manufactured is limited, a temporary fixture is often satisfactory.



One radio manufacturer has a group of three men who spend their entire time making fixtures, mainly for assembly operations. The group consists of a designer and two carpenters. The designer is a practical man with ingenuity, imagination, and considerable inventive ability. The designer, as well as the carpenters, is well grounded in the principles of motion economy. Although the foremen, industrial engineers, and operators all make suggestions as to the fixtures needed for the best method of doing a task, the three men contribute much to the success of the motion study program in the plant.

Nearly all assembly fixtures in this plant are made from maple wood, impregnated with oil to prevent change in dimensions due to change in weather conditions. Standard bins, holders for soldering irons and screwdrivers, and supports for power wrenches are available. A laboratory has been set up to try out ideas that are likely to require considerable experimentation.

**4. HAND MOTIONS SHOULD BE CONFINED TO THE LOWEST CLASSIFICATION WITH WHICH IT IS POSSIBLE TO PERFORM THE WORK SATISFACTORILY.**

The five general classes of hand motions are listed below in progressive order. The lowest classification which is shown first usually requires the least amount of time and effort and probably produces the least fatigue.

**General Classification of Hand Motions:**

1. Finger motions.
2. Motions involving fingers and wrist.
3. Motions involving fingers, wrist, and forearm.
4. Motions involving fingers, wrist, forearm, and upper arm.
5. Motions involving fingers, wrist, forearm, upper arm, and shoulder. This class necessitates disturbance of the posture.

The classification of hand motions is given here because it helps emphasize that material and tools should be located as close as possible to the point of use and that motions of the hands should be as short as the work permits.

A glaring example of poor location of material is shown in Fig. 135. Not only must the operator use the fifth classification of hand motions here but he must also twist and bend his back in order to get parts from the tote box at the right of the drill press. By simply emptying the parts from the tote box into a bin with a sloping bottom located



on the drill press table, the task of procuring parts is made easier and requires less time than in the first case.

The results of a study<sup>a</sup> of the time required to make hand motions of varying lengths are given in Tables XV and XVI. The operation

TABLE XV

SUMMARY OF TIME REQUIRED FOR HAND MOTIONS OF VARYING LENGTHS

Transport Empty

Study No.	Operator No.	Distance in Inches	Time in Minutes			
			Average	Mode	Maximum	Minimum
C17	A2	8	0.0037	0.004	0.004	0.003
C18	A2	16	0.0035	0.004	0.004	0.003
C19	A2	24	0.0049	0.005	0.005	0.004
C20	A1	8	0.0037	0.004	0.004	0.003
C21	A1	16	0.0053	0.005	0.006	0.005
C22	A1	24	0.0066	0.0065	0.008	0.006

TABLE XVI

SUMMARY OF TIME REQUIRED FOR HAND MOTIONS OF VARYING LENGTHS

Transport Loaded

Study No.	Operator No.	Distance in Inches	Time in Minutes				Average Velocity in Feet per Minute
			Average	Mode	Maximum	Minimum	
C17	A2	8	0.0040	0.004	0.004	0.004	167
C18	A2	16	0.0057	0.006	0.006	0.005	234
C19	A2	24	0.0059	0.006	0.007	0.005	339
C20	A1	8	0.0050	0.005	0.005	0.005	133
C21	A1	16	0.0070	0.006	0.010	0.006	190
C22	A1	24	0.0080	0.008	0.012	0.006	250

<sup>a</sup> See page 138.



was the forming of links for a portable typewriter. Although no general conclusions can be drawn from these data it is apparent that on this operation 30 to 75 per cent more time was required to make motions 24 inches long than motions 8 inches long.

As desirable as it may be to keep hand motions as short as possible, it is incorrect to assume that finger motions are less fatiguing than motions of the forearm. One has only to remember his early instructions in writing to know that free, loose forearm and wrist movements are easier, faster, and more uniform than finger motions. In fact the substitution of a telegraph key which moved in the lateral direction for the vertical movement key was the result of the observation that the lateral movement permitted the operator to work with a freer and looser wrist.<sup>10</sup>

In another investigation of movements, it was found that the finger motions were more fatiguing, less accurate, and slower than the motions of the forearm.<sup>11</sup> All evidence seems to show that the forearm is the most desirable member to use for light work and that in highly repetitive work the motions about the wrist and elbow are in all respects superior to those of the fingers or shoulders.

**5. MOMENTUM SHOULD BE EMPLOYED TO ASSIST THE WORKER WHEREVER POSSIBLE, AND IT SHOULD BE REDUCED TO A MINIMUM IF IT MUST BE OVERCOME BY MUSCULAR EFFORT.**

The momentum of an object is its mass multiplied by its velocity. In most kinds of factory work the total weight moved by the operator may consist of three things: the weight of the material moved, the weight of the tools or devices moved, and the weight of the part of the body moved.<sup>12</sup> It is often possible to make use of momentum of the hand, the material, or the tool to do useful work. When a forcible stroke is required, the motions of the worker should be so arranged that the stroke is delivered when it reaches its greatest momentum.<sup>13</sup> In laying a brick wall, for example, "If the bricks are conveyed from the stock platform to the wall with no stops, the momentum can be

<sup>10</sup> M. Smith, M. Culpin, and E. Farmer, "A Study of Telegrapher's Cramp," Industrial Fatigue Research Board, *Report* 43, 1927.

<sup>11</sup> R. H. Stetson and J. A. McDill, "Mechanisms of the Different Types of Movement," *Psychological Monograph*, Vol. 32, No. 3, Whole No. 145, p. 37, 1923.

<sup>12</sup> F. B. Gilbreth, "Motion Study," p. 63, D. Van Nostrand Co., New York, 1911.

<sup>13</sup> C. S. Myers, "Industrial Psychology in Great Britain," p. 88, Jonathan Cape, Ltd., London, 1926.



made to do valuable work by assisting to shove the joints full of mortar. If, instead of being utilized, the momentum must be overcome by the muscles of the bricklayer, fatigue . . . will result."<sup>14</sup>

The improved method of candy dipping explained on page 223 is another illustration of the utilization of momentum for the performance of useful work. The piece to be dipped was submerged under the surface of the melted sugar by the right hand at the end of a long return stroke of the hand. The momentum developed in this movement of the hand and the empty dipping fork was used in doing useful work instead of being dissipated by the muscles of the dipper's arm.

There are many times when momentum has no productive value. Its presence is undesirable in that the muscles must always counteract the momentum developed. When such is the case the three classes of weight or mass named above should be studied for the purpose of reducing each to the minimum. In addition, the velocity of the motions should be kept low by using the shortest motions possible.<sup>15</sup> There are a number of tools that are most effective when they are made as light in weight as possible. Such tools do not depend upon momentum or the use of a blow to function properly. For many kinds of work a heavy shovel or a heavy trowel is more fatiguing to use than a light one of the same dimensions and rigidity.

There are many additional considerations which enter into the determination of the proper size and weight of materials and tools to be used to produce maximum efficiency. Unfortunately there are little accumulated data that are of value here. Each case, as a rule, is surrounded by circumstances and conditions peculiar to itself. Consequently each problem must be the subject for special investigation.

**6. SMOOTH CONTINUOUS MOTIONS OF THE HANDS ARE PREFERABLE TO ZIGZAG MOTIONS OR STRAIGHT-LINE MOTIONS INVOLVING SUDDEN AND SHARP CHANGES IN DIRECTION.**

The simple operation of moving a pencil back and forth across a sheet of paper consists of two phases, the movement and the stop and change direction. The results of a study<sup>16</sup> of the simple hand motions *transport loaded* (away from the body), *stop* and *change direction*, and

<sup>14</sup> F. B. Gilbreth, "Motion Study," p. 78, D. Van Nostrand Co., New York, 1911.

<sup>15</sup> Short motions are relatively slow motions. For data on average velocities of hand motion see Table XVI.

<sup>16</sup> Investigation by Wayne J. Deegan, University of Iowa Studies in Engineering, *Bulletin* 6, pp. 37-51, 1936. Also see results of study by A. B. Cummins, University of Iowa Studies in Engineering, *Bulletin* 12, pp. 8-18.



transport loaded (toward the body) are given in Fig. 136. This figure shows that 75 to 85 per cent of the time to make a complete back and forth movement is used in actually moving the hand, and the remaining 15 to 25 per cent of the time is used in changing direction of the hand; that is, during the 15 to 25 per cent of the time the hand and the pencil are motionless. Further studies<sup>16</sup> show that continuous

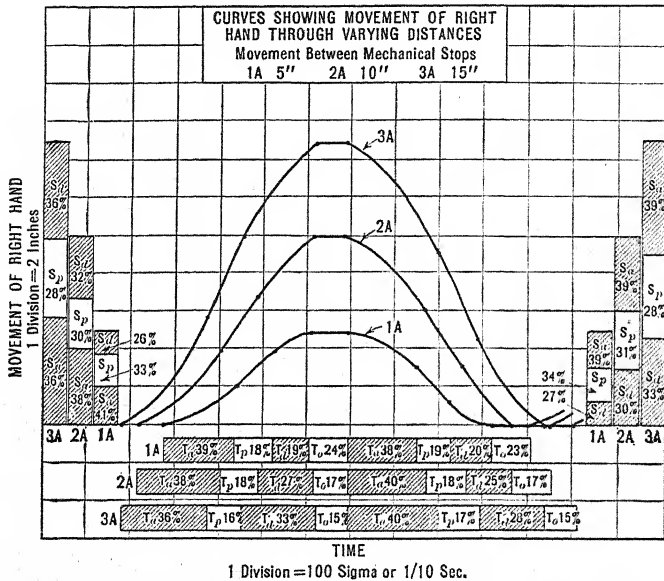


FIG. 136. Curves showing movement of right hand through varying distances—between mechanical stops.

curved motions are preferable to straight-line motions involving sudden and sharp changes in direction. Such abrupt changes in direction are not only time consuming but they are fatiguing to the operator.

In many jobs in the shop and office it is possible to use these smooth curved motions. Some examples will be given here. The first is that of folding rectangular sheets of paper used in packing X-ray films. The sheets vary in size from 3 inches by 5 inches to 12 inches by 15 inches folded. Although several million of these sheets of paper are folded per year it was found to be more economical to fold them by hand than by machine because of the many different sizes used.

**Old Method of Folding Paper.** The worker, holding a smooth piece of bone in the palm of her right hand (see Fig. 137), grasped the lower right-hand corner A of the sheet of paper to be folded. She

<sup>16</sup> See footnote 16 on page 219.



folded this end of the sheet over to point *B*, where the two hands matched or lined up the two corners of the sheet of paper. Then, swinging the right hand away from the body and using the bone as a creasing tool, she struck the folded sheet of paper about midpoint at *C*, creasing the fold from *C* to *D*. At *D* she stopped and changed direction abruptly, doubled back, creasing the entire length of the fold from *D* to *E*. At *E* the hand again changed direction and swung around to *F*, where the end of the bone was inserted under the edge of the creased sheet to assist the left hand in disposing of it on the pile of folded sheets at *G*.

**Improved Method of Folding Paper.** In the improved method the worker grasps the lower right-hand corner *A* of the sheet of paper to be folded. (See Fig. 138.) She folds this end of the sheet over to point *B*, where the two hands match or line up the two corners of the sheet of paper. She then moves the right hand through a smooth "S" curve, the bone striking the paper and beginning to crease at *X* and ending at *Y*. Thus the entire crease is completed with the single stroke of the bone. The hand then swings around in a curved motion from *Y* to *Z*, where, as in the old method, the end of the bone is inserted under the creased sheet to assist the left hand in disposing of it on the pile of folded sheets at *G*.

**Results.** By using the improved method described above only one creasing motion was required to complete the cycle instead of the two (one short and one long one) in the old method. Moreover, in the improved method two curved motions of the hand were used instead of two complete change directions and one 90-degree change direction in the old method.

A micromotion study of these two methods shows that 0.009 minute was required to crease the fold by the old method and 0.005 minute by the improved method. The improved method of creasing the fold, plus some other changes in the cycle, reduced the total time from 0.058 to 0.033 minute per cycle, enabling the operator to increase her output 43 per cent.

Another illustration of the value of curved motions over straight-line motions involving sudden changes in direction is given below.<sup>17</sup> The operation is dipping candy.

**Old Method of Dipping Candy.** The dipping process was carried out in the following manner. A "center" (an almond, walnut, Brazil

<sup>17</sup> E. Farmer, "Time and Motion Study," Industrial Fatigue Research Board, Report 14, pp. 36-41, 1921. Figures 139 and 140 reproduced by permission of the Controller of H. M. Stationery Office, London.



nut, or caramel) was placed in a pot containing melted sugar by using the left hand, and was covered with the melted sugar by working it with a fork held in the right hand. The finished piece of candy was then placed with the right hand on the tray to the right of the operator. Approximately 2 seconds were required to dip each piece.



FIG. 137. Path of hand in creasing folded sheet of paper—old method. There is an abrupt change in direction at *D* and also at *B*. Two strokes of the bone are used to crease the fold.

Although the lines in Fig. 139 do not show the exact movements of the right hand, they give a picture of the principal motions used. While the left hand was placing a center in the container of melted sugar, the right hand carried the empty fork from the tray *A* to the container *B*, and took up some of the thick melted sugar and pulled it over the center at *X*. When the hand reached *C* it moved to the left side of the container, the center being carried along with the end of the fork under it. The center was picked up at *D* and carried to the tray where it was deposited. The objections to this method of dipping were that the hand stopped at *B* (in Fig. 139) and changed direction sharply, and then at *C* the direction was almost reversed. This stop-



ping and sudden changing of direction placed unnecessary strain on the muscles of the arm.

**Improved Method of Dipping Candy.** The improved method of dipping is shown diagrammatically in Fig. 140. The center is dipped by a smooth sweeping motion of the hand instead of by a number of



FIG. 138. Path of hand in creasing folded sheet of paper—improved method. The hand makes a smooth "S" curve, creasing the fold with one stroke of the bone. Output was increased 43 per cent.

short zigzagging motions as in the old method. In the improved method the hand, after disposing of the finished piece of candy on the tray, moves from A to B as before, but reaches B "in the middle of an inward and downward curve with the hand in its strongest position for doing work." This makes it possible to utilize the momentum developed in the movement A-B in doing the most fatiguing part of the work, the dipping being the part of the process that offers the greatest resistance to the hand. In the old process this dipping motion was made by a short backward movement just after the hand had stopped and changed its direction. Furthermore, the momentum developed during the motion A-B was wasted in the old method since the hand



motion was checked at *B* in order to change its direction. By using the downward motion of the hand in the improved method, the melted sugar is swept over the center and, going under the surface in the second part of the curve, it comes up at *C*. The piece of candy is then deposited on the tray with a circular motion to "finish off" the candy. In the new method the hand takes easy smooth movements with all changes in direction effected by curves.

**Results.** The improved method was taught to a group of workers in the factory, and after a short period of training an average increase in production of 27 per cent resulted. However, since many workers had used the old method for years it was difficult to persuade some of them to give the new method a fair trial. As a new dipping room

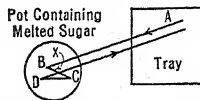


FIG. 139. Old method of dipping candy.

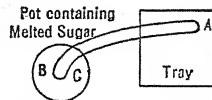


FIG. 140. Improved method of dipping candy.

equipped with new-style tables and trays was being started, new operators were trained in the proper method of dipping. After 3 months' work in this new room these new workers were producing an average of 88 per cent more than the workers of the same standing in the original room.

**Coal Mining.** In an investigation in coal mining it was found that the miners tired themselves unnecessarily by the sudden checking of the upward stroke of the pick and in accelerating again for the downward stroke. They were taught to use a slightly continuous path in swinging the pick, and to strike harder at a slower speed against the coal face.<sup>18</sup>

## 7. BALLISTIC MOVEMENTS ARE FASTER, EASIER, AND MORE ACCURATE THAN RESTRICTED (FIXATION) OR "CONTROLLED" MOVEMENTS.

Voluntary movements of the members of the human body may be divided into two general classes or groups.

A. In the *fixation* or controlled movements, opposing groups of muscles are contracted, one group against the other. For example, in bringing the pencil down to the paper preparatory to writing, two or

<sup>18</sup> E. Farmer and others, "An Investigation in a Coal Mine," *Journal of the National Institute of Industrial Psychology*, Vol. 1, No. 4, pp. 125-131, October, 1922.



more sets of muscles are in action. The positive sets of muscles propel the hand and the antagonistic sets oppose the movement. When the two sets of muscles act in an uneven or unbalanced manner, motion of the hand results. When the two sets of muscles exactly balance each other, the hand remains in a fixed position, although it is ready to act in any direction at any instant. The finger-and-thumb method of writing is an excellent illustration of fixation movements.

*B.* The *ballistic* movement is a fast easy motion caused by a single contraction of a positive muscle group with no antagonistic muscle group contracting to oppose it. The contraction of the muscles throws the member of the body into motion and since these muscles act only through the first part of the movement the member sweeps through the remainder of the movement with its muscles relaxed. The ballistic movement is controlled by the initial impulse and once under way its course cannot be changed.<sup>19</sup> A ballistic stroke may terminate (1) by the contraction of the opposing muscles, (2) by an obstacle, or (3) by dissipation of the momentum of the movement, as in swinging a golf club.

The ballistic movement is preferable to the fixation movement and should be used whenever possible. It is less fatiguing since the muscles contract only at the beginning of the movement and are relaxed for the remainder of the movement. The ballistic movement is more powerful, faster, more accurate, and is less likely to cause muscle cramp. It is smoother than the fixation movement which is caused by the contraction of two sets of muscles, one acting against the other continuously. The skilled carpenter swinging his hammer in driving a nail illustrates a ballistic movement. He aims his hammer, then throws or swings it. The muscles are contracted only during the first part of the movement; they idle along the rest of the way. The swinging curves of an orchestra conductor's baton is another illustration of ballistic movement. P. R. Spencer understood the value of ballistic movements, for the "free-hand writing" which he taught is known to every one to produce greater speed and accuracy with less fatigue than is possible with the finger-and-thumb method of writing, where the muscles of the hand are tightly drawn. The ballistic movement is the one taught to telegraph operators, piano players, violin players, athletes, etc., all of whom must use fast and accurate motions or movements.

<sup>19</sup> L. D. Hartson, "Analysis of Skilled Movements," *The Personnel Journal*. Vol. 11, No. 1, pp. 28-43, June, 1932.



It is not difficult to develop the free, loose, easy movements of the wrist and forearm. The hand should move about the wrist for the shorter motions and the forearm about the elbow for the longer motions. Experiments show that the wrist and elbow movements are faster than finger or shoulder movements.<sup>20</sup>

**8. RHYTHM IS ESSENTIAL TO THE SMOOTH AND AUTOMATIC PERFORMANCE OF AN OPERATION, AND THE WORK SHOULD BE ARRANGED TO PERMIT AN EASY AND NATURAL RHYTHM WHEREVER POSSIBLE.**

Rhythm may be interpreted in two different ways. Perhaps it is most frequently understood to mean the speed or the rapidity with which repeated motions are made. The reference is commonly made to the rhythm of walking or breathing. The operator feeding material into a machine is said to work with a rhythm depending upon the speed of the machine. Rhythm, then, in this sense, refers to the regular repetition of a certain cycle of motions by an individual.

Rhythm may be interpreted in a second way: <sup>21</sup>

A movement may be perfectly regular, uniform, and recurrent and yet not give the impression of rhythm. If one moves the hand or the arm in a circle, the hand may be made to pass a point in a circle much oftener per second than the tempo of the slower rhythms requires, and yet there will be no feeling of rhythm *so long as the hand moves uniformly and in a circle*. In order to become rhythmic in the psychological sense, the following change in the movement is necessary: The path of the hand must be elongated to an ellipse; the velocity of the movement in a part of the orbit must be much faster than in the rest of the orbit; just as the hand comes to the end of the arc through which it passes with increased velocity, there is a feeling of tension, of muscular strain; at this point the movement is retarded, almost stopped; then the hand goes on more slowly until it reaches the arc of increased velocity. The rapid movement through the arc of velocity and the sudden feeling of strain and retarding at the end of this rapid movement constitute the beat. In consciousness they represent one event, and a series of such events connected in such a movement-cycle may be said provisionally to constitute a rhythm. Every rhythmic beat is a *blow*. . . . In all forms of activity where a rhythm is required, the stroke, the blow, the impact, is the thing; all the rest is but connection and preparation.

Rhythm, either in the sense of a regular sequence of uniform motions, or in the sense of a regular sequence of accented motions, is of value to the worker. Uniformity, ease, and even speed of work are

<sup>20</sup> Wm. L. Bryan, "On the Development of Voluntary Motor Ability," *The American Journal of Psychology*, Vol. 5, No. 2, p. 171, November, 1892.

<sup>21</sup> R. H. Stetson, "A Motor Theory of Rhythm and Discrete Succession," *Psychology Review*, Vol. 12, No. 4, p. 258, 1905.



promoted by the proper arrangement of the work place, tools, and materials. The proper sequence of motions enables the worker to establish a rhythm which assists in making the operation practically an automatic performance—the operator does the work without mental effort.

In many kinds of work there is an opportunity for the operator to accent certain points in a cycle of motions. For example, every punch-press operator, feeding the press by hand, tends to feed the sheet of material forward with a sudden thrust which constitutes an accented point in the cycle. Where the work permits it is most natural for the worker to fall into a rhythm in this second sense.

**Individual Rhythm.** Some have suggested that each individual has a "natural" rhythm or speed of movement that permits him to work with least effort. Some have urged that individuals should be permitted to work at this natural speed and that no outside force, such as a wage incentive, should be exerted to cause the individual to work faster than his natural rhythm.<sup>22</sup> Since it seems difficult to determine what the natural rhythm is for any person and since most workers can be taught to change their rhythm in performing the same work (such as working at different speeds or using different sets of motions), it seems that too much emphasis should not be placed on this so-called natural rhythm. Habit acts in a powerful way to affect the speed and the sequence of motions which a worker uses in performing a task. Once the habit is formed, it *does* require real effort on the part of the worker to change or modify this habit. To illustrate this point, a typewriter company had several polishers of long experience who had for several years been polishing a particular part of the typewriter. These polishers had been accustomed to take a definite number of strokes across the polishing wheel, and they knew the finish that the piece should have to pass inspection. In a new design of the typewriter this particular piece was located in a more obscure position than formerly and so it did not need such a high polish. The polishers were told just how the piece was to be polished for the new typewriter and they were carefully instructed as to the finish that would now be required to pass inspection. The operators, however, found it difficult to change their habits. They "forgot" to take fewer strokes, and as a result they were turning out work that was of higher quality than needed and their output was lower than it should have been. With constant and persistent atten-

<sup>22</sup> E. Farmer, "Time and Motion Study," *Engineering and Industrial Management*, Vol. 7 (N.S.), No. 5, p. 138, London, Feb. 2, 1922.



tion these polishers, after 4 days, were able to produce the parts of just the quality finish required and at a proportionately faster speed in pieces per hour.

Nearly every worker finds that a conscious effort and some persistence are required to do a new task or to perform an old one in a new way. However, for most people this change is by no means impossible and usually it can be readily made. There are cases where a certain sequence of motions has been made by a person for such a long period of time that it is unwise to try to change it. This can, perhaps, also be said about the speed at which some people work.

When a worker becomes fatigued or when he is distracted or voluntarily wishes to produce less, he may either slow down his speed and maintain a slower rhythm, or he may introduce delays or interruptions, in the form of extra motions, into the cycle.

**Effect of Fatigue on Rhythm.** In a study of polishing in a silverware factory, it was found that during the morning the polishers worked at a uniform rate and the units were finished at regular intervals.<sup>23</sup> In the afternoon, however, the time per unit increased. Also the pressure used in holding the knife or the spoon against the polishing wheel increased; more strokes were used and the time for polishing each piece was greater than in the morning when a regular rhythm was maintained. Fatigue, then, seems to break up the rhythm and disturb the coordination that makes for rapid and easy work. Quoting from the report, "The tired worker is, therefore, not only working slower than when she is fresh, but is also expending her energy extravagantly."<sup>24</sup>

<sup>23</sup> E. Farmer and R. S. Brooke, "Motion Study in Metal Polishing," Industrial Fatigue Research Board, *Report 15*, pp. 1-65, 1921.

<sup>24</sup> *Ibid.*, p. 51.



## CHAPTER 16

### PRINCIPLES OF MOTION ECONOMY AS RELATED TO THE WORK PLACE

#### ***9. THERE SHOULD BE A DEFINITE AND FIXED PLACE FOR ALL TOOLS AND MATERIALS.***

The operator should always be able to find the tools and materials in the same location. Likewise, finished parts and assembled units should be disposed of in fixed places. For example, in the assembly of the bolt and washers, the hand should move without mental direction to the bin containing the rubber washers, then to the bin containing the steel washers, then to the lock washers, and finally to the bolts. It should be unnecessary for the operator to have to think where the materials are located.

Definite stations for materials and tools aid the worker in habit formation, permitting the rapid development of automaticity. It cannot be emphasized too strongly that it is greatly to the worker's advantage to be able to perform the operation with the least conscious mental direction. Frequently, materials and tools are scattered over the work place in such a disorderly fashion that the operator must not only exert mental effort, but must also hunt around in order to locate the part or tool needed at a given instant. The workers are very much in favor of having definite stations for materials and tools, since this reduces fatigue and saves time. There can be no virtue in requiring the worker to exert the unnecessary effort of deciding just what tool to pick up next or what part to assemble next, when, by simply arranging the materials and tools properly, the operator, with a little practice, will automatically perform the work in the proper sequence, at a rapid rate, and with a minimum expenditure of effort.

When the eyes must direct the hand in reaching for an object, the eyes ordinarily precede the hand. However, if materials or tools are located in a definite place and if they are always grasped from the same place, the hand automatically finds the right location and in many cases the eyes may be kept fixed on the point where the tools or materials are used.



**Shipping Room Table.** Motion study principles have been successfully applied in many "nonmanufacturing" activities such as offices, restaurants, hotels, department stores, and mail order houses. Figure 141 shows a special semicircular work table designed for weighing, stamping, and billing parcel post packages in the shipping room of a

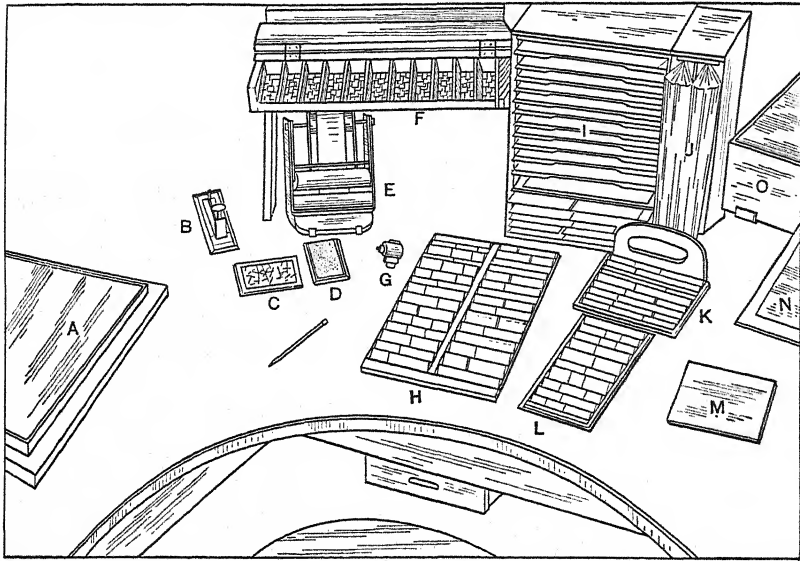


FIG. 141. Special table for weighing, stamping, and billing parcel-post packages for shipment in mail-order house. A. Scales; B. Stapler; C. Pin-disposal box; D. Stamp pad; E. Gum tape dispenser; F. Postage stamps; G. Counter; H. Refund vouchers; I. Supply of form letters; J. Re-order blanks; K. "Due us" forms; L. Postal collection forms; M. Scratch pad; N. Adding machine; O. Irregular billing papers.

large mail order house.<sup>1</sup> The packages to be shipped come down to the work table on a slide at the extreme left of the table, are weighed, stamped, billed, and pushed off onto a belt conveyor at a point adjacent to the incoming slide. It is not necessary to lift the package. Note that the table has "cutouts" for scales, pins, forms, stamp pad, adding machine, etc. A drawer under the table provides a place for the operator's personal belongings. This work place layout is typical of the care with which every activity in this organization has been studied and indicates how the work has been made easier.

<sup>1</sup> Illustration and data courtesy of John A. Aldridge.



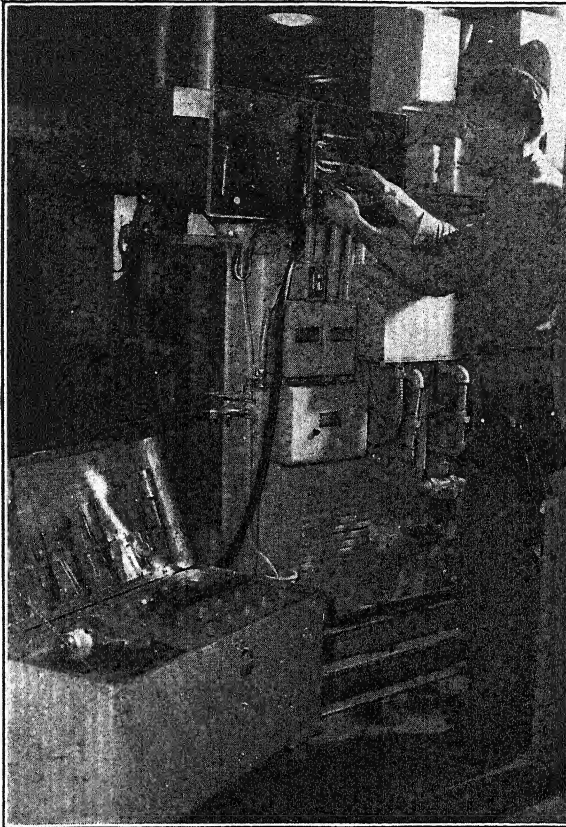


FIG. 142. Special tool chest—trucks are provided for maintenance electricians at Douglas Aircraft Company plants. Service cribs or shops are centrally located in the production areas, thus enabling electricians to answer trouble calls by traveling short distances with all the tools they will need.<sup>2</sup>

**10. TOOLS, MATERIALS, AND CONTROLS SHOULD BE LOCATED CLOSE IN AND DIRECTLY IN FRONT OF THE OPERATOR.**

Very frequently the work place, such as a bench, machine, desk, or table, is laid out with tools and materials in straight lines. This is incorrect, for a person naturally works in areas bounded by lines which are arcs of circles.

**Normal Working Area.** Considering the horizontal plane, there is a very definite and limited area which the worker can use with a

<sup>2</sup> "Decentralized Maintenance for Continuous Output," by A. T. Kuehner, *Factory Management and Maintenance*, Vol. 101, No. 3, pp. 123-128, March, 1943.



normal expenditure of effort. There is a normal working area for the right hand and for the left hand, working separately, and for both hands working together. (See Figs. 143 and 144.) The normal working area for the right hand is determined by an arc drawn with a sweep

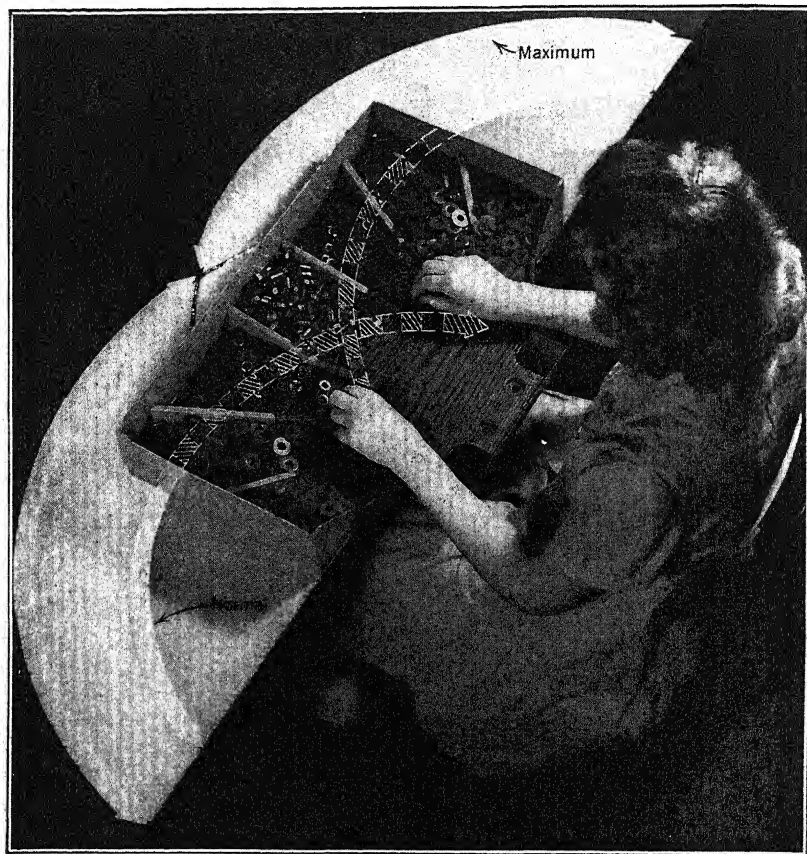


FIG. 143. Normal and maximum working areas in the horizontal plane.

of the right hand across the table. The forearm only is extended, and the upper arm hangs at the side of the body in a natural position until it tends to swing away as the hand moves toward the outer part of the work place. The normal working area for the left hand is determined in a similar manner. The normal arcs drawn with the right and left hands will cross each other at a point in front of the worker. The overlapping area constitutes a zone in which two-handed work may be done most conveniently.



**Maximum Working Area.** There is a maximum working area for the right hand and for the left hand, working separately, and for

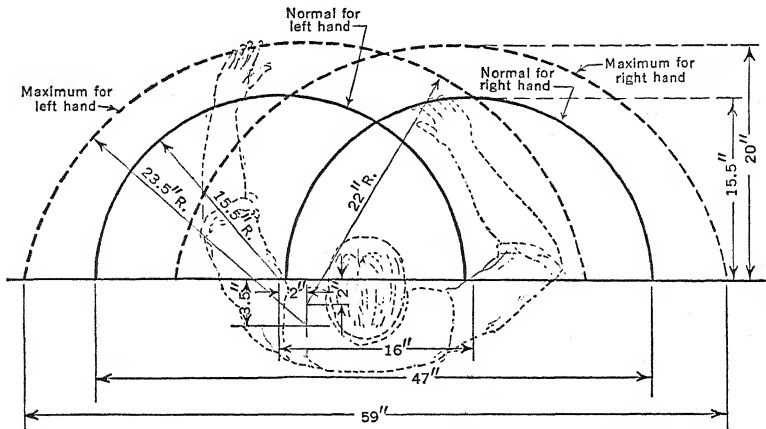


FIG. 144. Dimensions of normal and maximum working areas in the horizontal plane. Dimensions obtained from measurements made of thirty men.<sup>3</sup>

both hands working together. (See Figs. 143 and 144.) The maximum working area for the right hand is determined by an arc drawn with

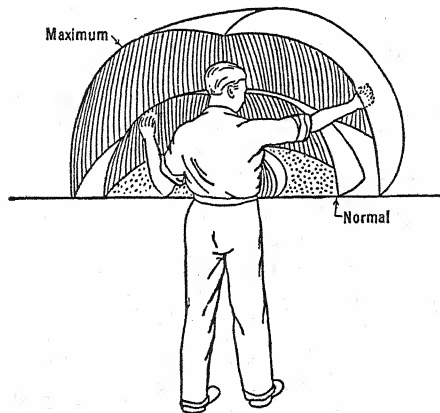


FIG. 145. Normal and maximum working space in three dimensions.

a sweep of the right hand across the table with the arm pivoted at the right shoulder. The maximum working area for the left hand is

<sup>3</sup> Dimensions taken from "A Study of Workplace Layout," a thesis by M. L. Asa, University of Iowa.



determined in a similar manner by an arc drawn with a sweep of the left hand. The overlapping area formed by these two maximum arcs constitutes a zone beyond which two-handed work cannot be performed without causing considerable disturbance of posture accompanied by excessive fatigue.

Each hand has its normal working space in the vertical plane as well as in the horizontal plane in which work may be done with the least time and effort. (See Fig. 145.) A maximum work space in the vertical plane may also be determined beyond which work cannot be

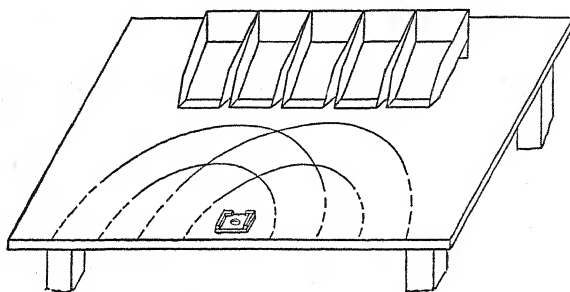


Fig. 146. Incorrect work place layout. Bins are located too far from the assembly fixture. The operator must bend forward to get parts from bins.

performed without disturbing the posture. In locating materials or tools above the work place, consideration should be given to these facts.

Figures 146 and 147 have been included in order to emphasize the importance of arranging the material *around* the work place and as close in as possible. In Fig. 146 the five bins containing material are outside the maximum working area, necessitating bending the body to reach them. In Fig. 147 the bins have been located within the normal working area, permitting a third-class motion which requires no movement of the body. The use of a duplicate fixture and duplicate bins arranged symmetrically on either side of the fixture permits the two hands to make simultaneous motions in opposite directions in performing the operation. Such an arrangement makes possible natural, easy, rhythmical movements of the arms.

Those tools and parts that must be handled several times during an operation should be located closer to the fixture or working position than tools or parts which are handled but once. For example, if an operation consists of assembling a number of screws into a metal switch plate, the containers for the screws should be placed closer to



the fixture than the containers for the plates. This is done because only one plate must be transported from the container to the fixture per cycle, whereas several screws would have to be transported from their containers to the fixture.

In considering the above point it is equally important to remember that the parts must be arranged in such a way as to permit the shortest eye movements, the fewest eye fixations, the best sequence of motions, and arranged to aid the operator in rapidly developing automatic and rhythmical movements.

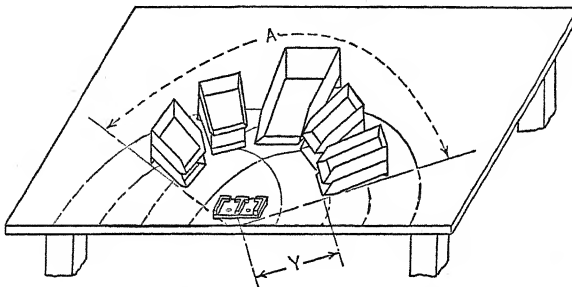


FIG. 147. Correct work place layout. Bins are located close to the fixture enabling the operator to get parts from any of the bins with easy quick forearm motions. In many kinds of work the eyes must direct the hands. In such cases the work area should be located directly in front of the operator so that eye fixations will be as few and as close together as possible. In other words, angle *A* should be as small as possible, and distance *Y* should be as short as the nature of the work will permit.

**Results of Moving Parts Closer to Fixture.** The production of one model of a radio requires the assembly of 260 separate parts or sub-assemblies. Two hand movements are required to pick up each part from the supply bin and process or assemble it—one movement of the hand to the bin and one from the bin. By shortening the distance 6 inches for reaching each of these parts there is a saving in time of 34,000 hours per year.

Number of parts moved	= 260
Movements (motion of hand to and from bin)	= 2
Average saving in time to move hand six inches shorter distance	= 0.002 minute

or

$$260 \times \frac{(2 \times 0.002)}{60} = 0.017 \text{ hour per radio set}$$



This saving of 0.017 hour or 62 seconds per radio set per day is extremely small. However, since this company makes 8000 sets per day, the savings per day would be:

$$8000 \times 0.017 = 136 \text{ hours per day}$$

Consider this production to run 250 working days per year:

$$250 \text{ days} \times 136 \text{ hours per day} = 34,000 \text{ hours saved per year}$$

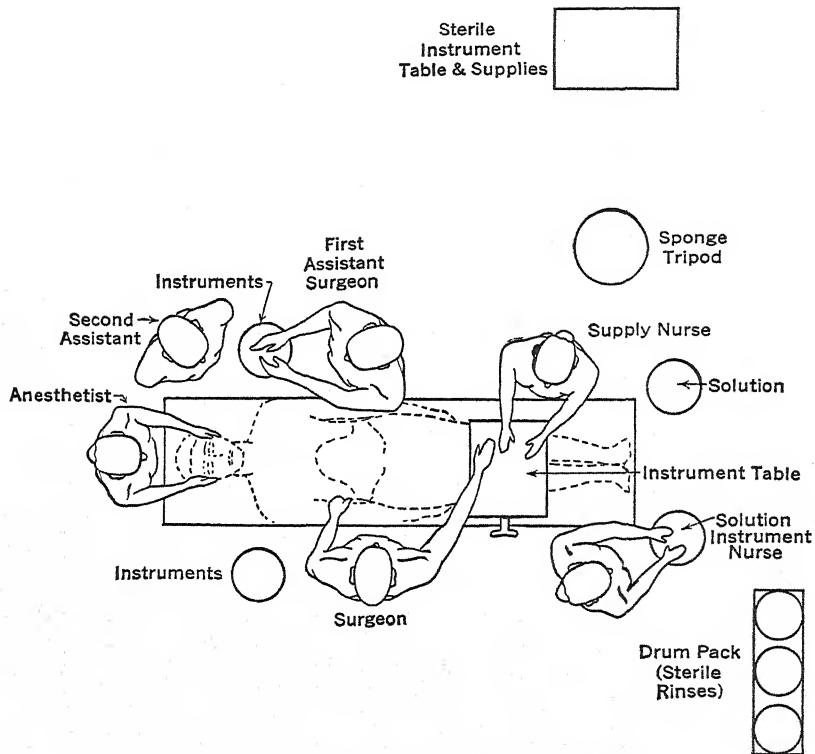


Fig. 148. Conventional operating-room setup.

Another way to look at this is in total distance saved. If 6 inches are saved in the movement of the hand to the bin and another 6 inches from the bin, the total savings are 12 inches, or 1 foot per piece.

$$260 \text{ pieces} \times 1 \text{ foot} = 260 \text{ feet saved per set}$$

$$8000 \text{ sets} \times 260 \text{ feet per set} = 2,080,000 \text{ feet or } 394 \text{ miles saved per day}$$

$$250 \text{ working days} \times 394 \text{ miles per day} = 98,500 \text{ miles saved per year}^4$$

<sup>4</sup> This case developed for use in RCA training course by G. A. Godwin while Industrial Engineer for RCA Victor Division of Radio Corporation of America.



**Arrangement of Operating Room in Hospital.** The accepted operating room practice causes much useless motion and delay on the part of assistants and nurses in handling instruments and supplies. (See Fig. 148.) The redesigned arrangements shown in Fig. 149 eliminates many motions in that the instruments and supplies are on either side of the surgeon, enabling the nurses to face the operating table instead of turning around to procure necessary articles from tables ordinarily located behind them.<sup>5</sup> The two tables are adjustable in

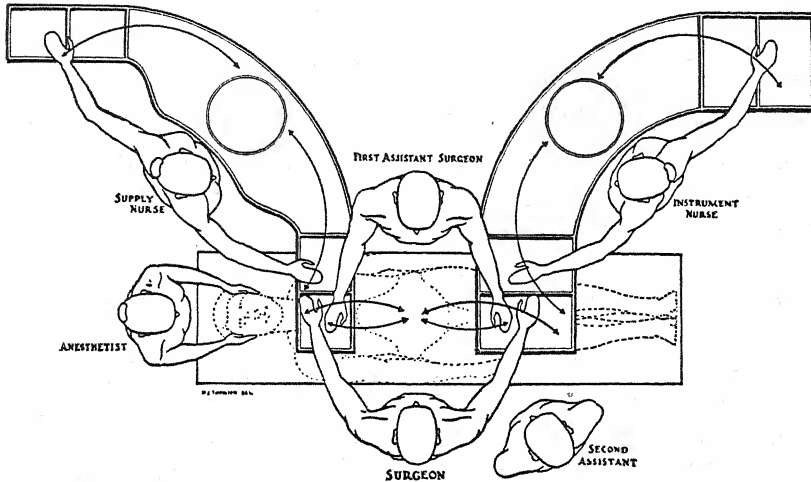


FIG. 149. Operating-room setup showing tables for instruments and supplies designed to facilitate the work of the surgeon, his assistants, and the nurses.

height, built with removable metal tops and separate basins for clean and soiled instruments.

**Office Desks.** The application of motion economy principles to many kinds of office and shop work has led to concentrated effort to improve the office desk. This is the way this problem was solved by Frank Lloyd Wright, designer of plant and furnishings for S. C. Johnson and Son, Inc.

<sup>5</sup> W. H. Lawrence and C. H. Berry, "Rhythmic Surgery," *The American Journal of Surgery*, Vol. XLI, No. 3, pp. 393-398, September, 1938. Figure 149 is used with the permission of *The American Journal of Surgery*.

For other material in this field, see T. S. Welton, "In Regard to 'Rhythmic Surgery,'" *The American Journal of Surgery*, Vol. XLI, No. 3, pp. 371-373, September, 1938; E. H. Pool and F. W. Bancroft, "Systematization of a Surgical Service," *Journal of the American Medical Association*, Vol. 59, pp. 1599-1603, November 10, 1917; F. B. Gilbreth, "Motion Study in Surgery," *Canadian Journal of Medicine and Surgery*, July, 1916.



Desks were designed and built to suit the operations to be performed on them. The basic desk has a top 84 inches long and 32 inches wide, a subshelf, and a top shelf for stationery racks and "in and out" letter trays. The subshelf is used to hold papers and reference books which might otherwise be piled on top of the desk; yet these are located conveniently for use when needed. The working surface is  $28\frac{1}{2}$  inches from the floor instead of 30 inches.



FIG. 150. Typist's desk.

The typist's desk shown in Fig. 150 has a section cut out of the top so that the typewriter sits on the lower level. Several variations of the standard desk have been developed with openings for comptometers, billing machines, and filing boxes cut out to bring the working surface to the proper height for easy use.

Among the advantages claimed for the desk is the substitution of hanging tills hinged to the front leg for drawers, making it possible for the operator to swing the till over to her for ease in use. Tills are either  $5\frac{1}{2}$  inches or 11 inches deep and are interchangeable so that different combinations can be made to fit the operator's needs. The



wastepaper basket is hung on the desk frame, where it is more convenient to use, less conspicuous, and out of the way when the floor is being cleaned.

The entire office consists of a single work room 128 feet by 208 feet with a 17-foot mezzanine all around it, all without partitions or obstructions. The arrangement of the office so that work flows in straight lines from department to department together with the new equipment has resulted in at least a 15 per cent increase in output for each division of the office, with some departments producing 25 per cent more work.

**Packing Books.** Figure 151 shows the arrangement of the work place for packing a book in shipping carton (see Fig. 152 B) and seal-



FIG. 151. Arrangement of work place for placing book in shipping carton and sealing carton with tape—improved method.

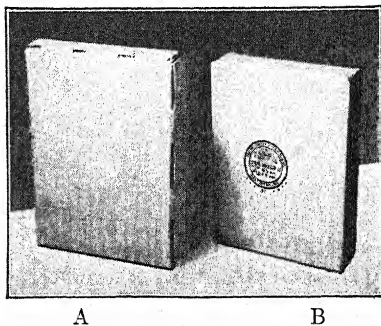


FIG. 152. Shipping carton containing encyclopedia. A. Carton sealed old way; B. Carton sealed improved way.

ing the carton by an improved method. The carton is folded around the wrapped book and the ends of the carton are folded over. The carton is then placed in a simple three-sided fixture which holds the edges in place while both hands apply the tape around three sides.

This improved method, worked out by James Morrison, saves 22 per cent in time, 43 per cent in amount of tape used, and produces a neater package and one that is several times stronger than the original one.

**Arrangement of Machines.** The following statement might be considered as a corollary to rule 10: *In the continuous or progressive type of manufacturing, machines, process apparatus, and equipment should be arranged so as to require the least possible movement on the part of the operator.*



The machines in Fig. 153 are laid out in a straight line along a trucking aisle. Space is provided between the machines for a skid platform on which material is placed before and after being processed.

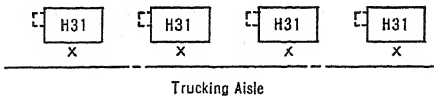


Fig. 153. Machines laid out in the conventional way. Material is moved to and from the machines on skid platforms by lift trucks. An aisle permits access to each machine.

Machines are frequently placed parallel to the conveyor as in Fig. 154. Such an arrangement, although better than the one illustrated in Fig. 153, still requires the operator to turn completely around in transporting material from the machine to the conveyor, and vice versa. A better arrangement is shown in Fig. 155, where the machines are placed perpendicular to the conveyor and close to it. This arrangement permits the operator to move material to and from the conveyor with less movement of the body.

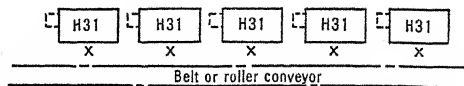


Fig. 154. Machines laid out parallel to a belt or roller conveyor. Material is moved to and from the machines by conveyor and no trucking aisle is needed. The operator turns through 180 degrees to use the conveyor.

There is still a fourth method of laying out machines which can often be used to advantage. (See Fig. 156.) The machines that can be operated by one man are grouped close together, so that the time required for the operator to move from loading one machine to removing the finished piece from

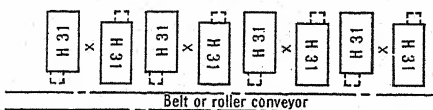


Fig. 155. Machines laid out perpendicular to a belt or roller conveyor. The operator turns through 90 degrees to use the conveyor.

process at A (skid platform in Fig. 156), the first operation being performed by machine H31, the next by machine L12, and the third operation by H31B. The machine time and the handling time would

When one man operates several machines it is necessary for him to walk a considerable distance because the machines are spread out over so much floor space.

The trucking aisle is unnecessary and walking is reduced when the machines are located along a conveyor.

moving the finished piece from the next, and loading it, is a minimum. Often machines used to perform successive operations on a part can be grouped together so that the part, in the form of a casting or forging, might begin the



have to be so balanced that the operator could keep the machines in operation without too much loss of machine time. From the third machine the part is sent, if necessary, to the next group of machines by means of a chute shown at *D*.

The Cadillac factory rearranged a number of their departments in a manner similar to that shown in Fig. 156. In one department, in particular, where front-wheel spindles were machined in a continuous process, the new arrangement saved 40 per cent of the floor space and seventeen men did the work of twenty-seven.<sup>6</sup>

**Shipping-Department Operations.** The application of motion economy principles to shipping-department operations may result in substantial savings in time and labor costs.

A packing bench and a checker's table designed by C. H. Cox for use in the shipping department of Merck & Company shows how the principle of locating materials and tools close in front of the operator made it possible for the operator to do his work more easily and faster.<sup>7</sup>

**Packing Bench.** The packing operation consisted mainly of packing for shipment bottles and boxes containing chemicals. Figure 157 shows the original 9-foot-long flat-top packing bench containing a tape machine, glue pots, nail boxes, hammer, stencil brush, knife, scissors, etc. Hoods, wrappers, and pads for individual container protection and special box labels were stored along the back half of the bench and in the cabinets below the working surface. None of the equipment or material was pre-positioned in definite locations. Since the actual packing was not done on this bench, all equipment and material were outside the maximum working area. Boxes were set up and packed on the 2-foot by 3-foot packing "buck" which was set perpendicular to the packing bench. A loose bale of excelsior was placed on the floor opposite the bench and on the left side of the buck.

The operator carried each piece of stock from shelf truck to bench; hooded or wrapped each item; carried it to the box; placed it in posi-

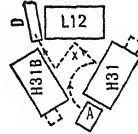


FIG. 156. Machines arranged in groups. Machine time and handling time are so balanced that one man can keep the entire group in operation. Material is moved by short conveyor or chute to the next group of machines where succeeding operations are performed on the part.

<sup>6</sup> F. J. Van Poppelen, "See What Motion Study Has Done to Plant Layout," *Factory and Industrial Management*, Vol. 82, No. 6, pp. 797-799, December, 1931.

<sup>7</sup> C. H. Cox, "Work Simplification Applied to the Shipping Department," *American Management Association*, Production Series 115, p. 3, 1939.



tion; stepped to the left for excelsior; stepped back to the box; and placed the excelsior. Each use of glue, labels, or stencil brush meant several steps along the packing-bench area. The operator in Fig. 157 is cutting tape for sealing the packed box on the buck.



FIG. 157. Packing bench—old design.

The new packing bench shown in Fig. 158 combines all three former units into one fixture. All equipment and material are conveniently positioned within the maximum working area. On the left is a tin-lined excelsior bin and on the right is a packing buck. A compartment for hammer, stencil brush, knife, etc., is located above the buck; above this is a drawer for nails and tacks; to the left of this drawer is a holder for the operator's pencil and a slide for his production record.



On the extreme right side of the bench, a shelf holds the tape dispenser; a large compartment houses a new-style glue-dispenser; then come four compartments for commonly used corrugated separators;

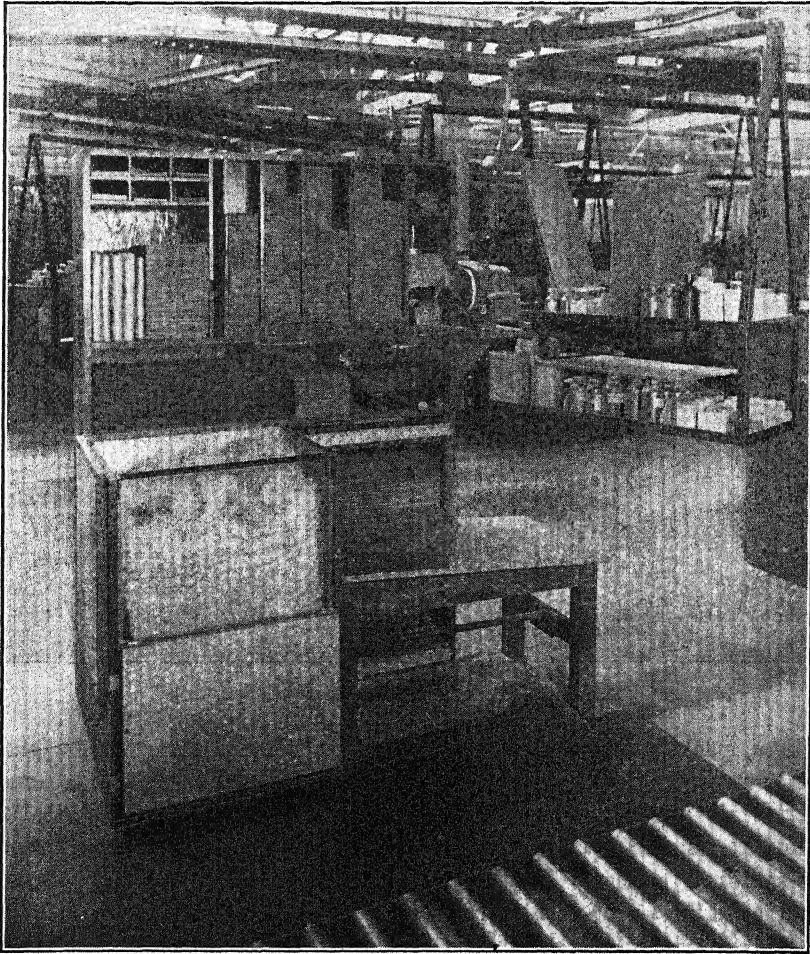


FIG. 158. Packing bench—improved design.

and a small pigeonhole slot for special stencils. The extreme left-hand side of the fixture contains material infrequently used, such as six sizes of special labels, asbestos pads, large-sized hoods, and long strips of corrugated wrappers.

If the operator desires to do so, he may stand in one position to select and make up the box; select stock to be packed from the mono-



rail carrier; reach glue and tape; select all internal packing material; reach necessary stencils and stencil brush; and record the work on his production record. Although it is not recommended that the operator stay in one fixed location, this packing bench has eliminated thousands of unnecessary steps for each packer every day.

**Checker's Table.** The checker's table shown in Fig. 159 is semi-circular in shape with individual compartments for shipping papers,

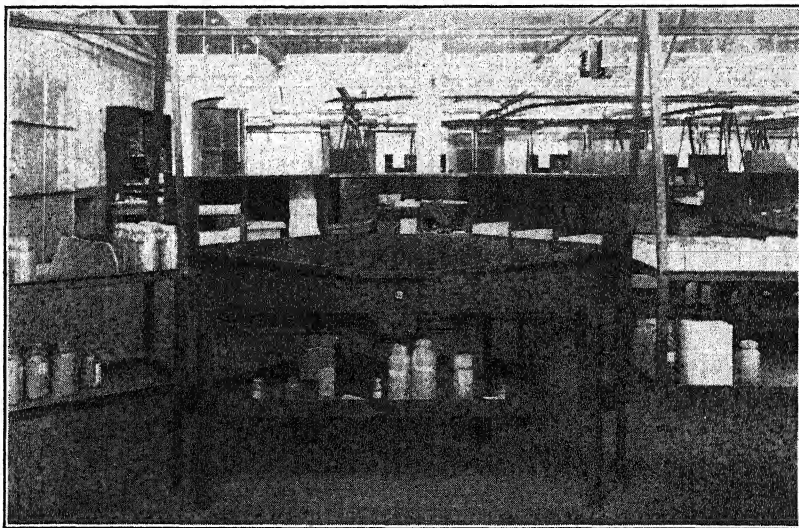


FIG. 159. Checker's table—improved design.

orders, packing memos, envelopes, rubber stamps, stamp pads, and other auxiliary equipment and materials.<sup>8</sup> Working edges of the compartments are within the maximum working area. The table also provides a sloping working surface of convenient height for an operator in standing position. The lower shelf provides space for the storage of special "put-ups" to be assembled with the regular stock items.

This improved table replaced an old-style bench 9 feet long with four large storage cabinets under the working surface, where miscellaneous material and equipment were kept.

The improved table eliminated the walking required to cover the old straight-table area; saved time because of conveniently located material and the proper height of writing surface; and conserved floor space.

<sup>8</sup> C. H. Cox, *op. cit.*, p. 10.



**11. GRAVITY FEED BINS AND CONTAINERS SHOULD BE USED TO DELIVER MATERIAL CLOSE TO THE POINT OF USE.**

A bin with sloping bottom permits the material to be fed to the front by gravity and so relieves the operator of having to dip down into the container to grasp parts. (See page 196.) However, it is not always possible to slide material into position as in the bolt and washer assembly. More frequently bins like those shown in Fig.

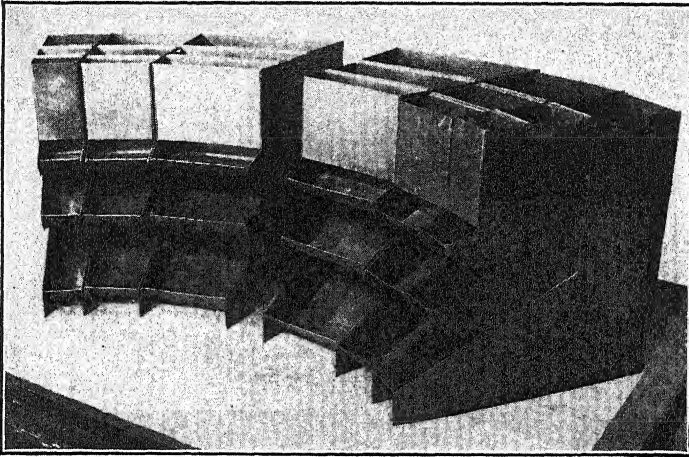


FIG. 160. Standard bins of the gravity-feed type.

160 are used. Where many different parts are required, as in the assembly of an electric switch, it becomes necessary to nest the bins one above the other in order to have the material within convenient reach of the operator.

Bins of standard sizes, such as those shown in Fig. 160, are standard equipment in many plants. The bins are interchangeable and are made in three heights and three widths. By the use of these standard unit bins, any combination can be made to suit the particular job. It is difficult to give a general rule as to the proper size of bins for a particular operation. Some companies try to have their bins large enough to hold material for 4 hours' work, which probably is an economical size for many kinds of material.

Figure 196 on page 287 shows how these bins were arranged for the assembly of a special doorknob. With such standard bins available it is a simple task to set up for a new job.



Figure 161 shows standard work-place equipment used by the RCA Manufacturing Methods Division.<sup>9</sup> Bins, tool holders, flat trays, and

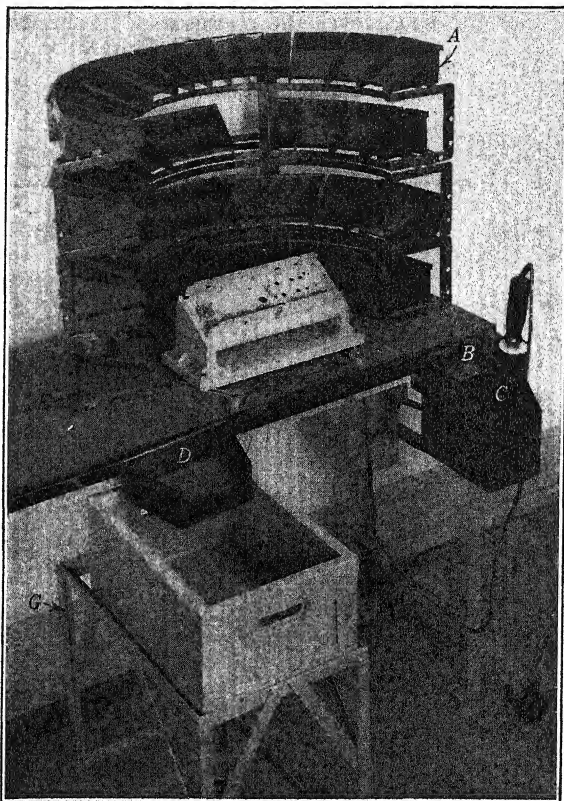


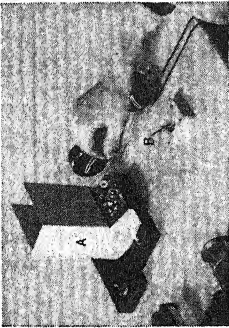
FIG. 161. Standard work place equipment. *A*. Lip tray, length (from back to lip)  $5\frac{1}{2}$  inches; width  $2\frac{1}{8}$  inches,  $4\frac{1}{4}$  inches, or  $8\frac{1}{2}$  inches. *B*. Edge tray, length (from back to lip)  $4\frac{1}{4}$  inches or  $8\frac{1}{2}$  inches; width  $5\frac{1}{2}$  inches. *C*. Open bin—bench type, length (from back to front) 8 inches; width 5 inches, 8 inches, or 10 inches; depth 8 inches. *D*. Open bin—rack type, length (from back to front) 8 inches; width at back  $8\frac{1}{2}$  inches; width at front  $5\frac{1}{2}$  inches; depth 3 inches. *E*. Curved rack to support trays, depth  $5\frac{3}{8}$  inches; height  $4\frac{7}{8}$  inches. *F*. Universal brackets for mounting fixtures. *G*. Tote box dolly designed to hold tote boxes of material or finished work.

solder iron holders, etc., are interchangeable and may be mounted with equal facility on a work bench, drill press, riveting machine, or

<sup>9</sup> Illustration and data courtesy of Joseph H. Quick, RCA Victor Division of Radio Corporation of America.



TABLE XVII  
TIME REQUIRED TO GRASP, CARRY, AND DISPOSE OF MACHINE-SCREW NUTS AND MACHINE SCREWS FROM VARIOUS TYPES OF BINS

		1—Hopper Type Bin		2—Rectangular Bin		3—Bin with Tray	
		Nuts	Screws	Nuts	Screws	Nuts	Screws
SELECT AND GRASP Nut or screw from bin at A (see figure above).	Time in Minutes	0.00629	0.00586	0.00653	0.00541	0.00390	0.00465
	Time in Per Cent (Shortest Time = 100%)	161	126	163	117	100	100
TRANSPORT LOADED Carry nut or screw through distance of 5 inches—from A to B.	Time in Minutes	0.00193	0.00339	0.00236	0.00418	0.00205	0.00318
	Time in Per Cent (Shortest Time = 100%)	100	106	123	132	106	100
RELEASE LOAD Drop nut into 1-inch hole in table top at B.	Time in Minutes	0.00404	0.00397	0.00360	0.00350	0.00368	0.00385
	Time in Per Cent (Shortest Time = 100%)	112	113	100	100	102	110
TRANSPORT EMPTY Move hand to bin at A for nut.	Time in Minutes	0.00152	0.00245	0.00233	0.00305	0.00198	0.00258
	Time in Per Cent (Shortest Time = 100%)	100	100	154	125	131	106
TOTAL CYCLE (G. + T. L. + R. L. + T. E.)	Time in Minutes	0.01377	0.01567	0.01480	0.01614	0.01160	0.01428
	Time in Per Cent (Shortest Time = 100%)	119	110	128	113	100	100



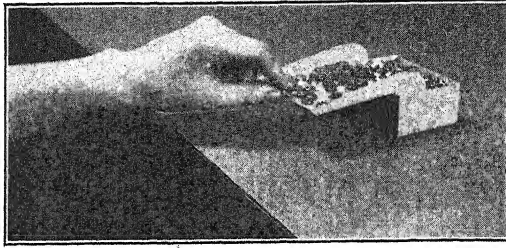


FIG. 162. Bin with tray attached to facilitate *select* and *grasp* of parts.

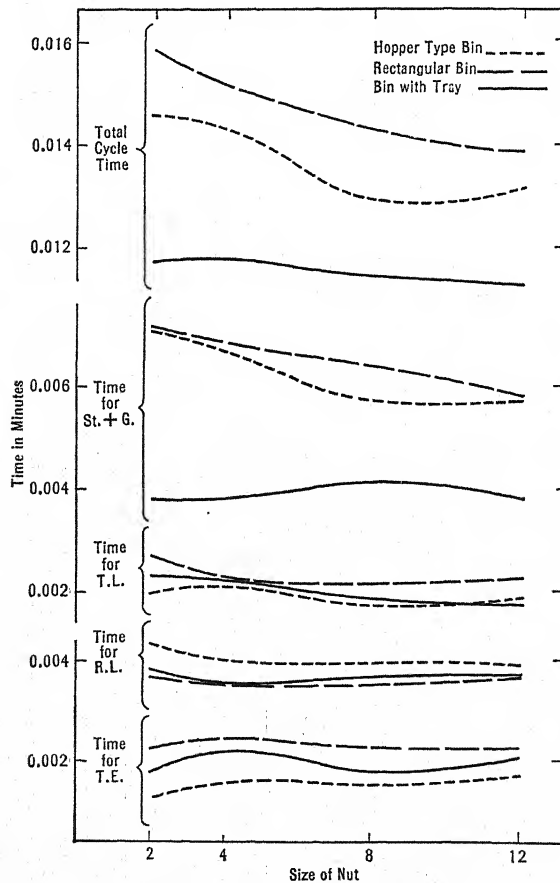


FIG. 163. Curves showing results of study of time required to grasp machine-screw nuts from various types of bins. Averages of median time values for five male and five female operators are shown.



hung on any standard rack in any position. This standard equipment is entirely flexible and can be readily adapted for use in the manufacture of new radio apparatus. When a new type of radio is to be put into production it is a simple matter to disassemble the standard

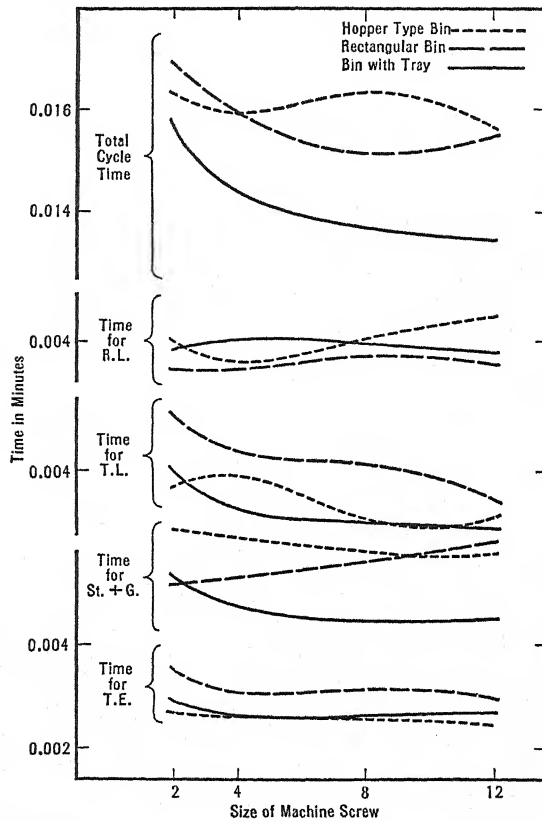


FIG. 164. Curves showing results of study of time required to grasp machine screws from various types of bins. Averages of median time values for five male operators are shown.

bins and equipment and set it up again for the new job. The work bench itself is made in standard sections and is fitted with pipe to carry compressed air and conduit for electric power. When a long bench is needed, several standard bench sections are bolted together, electric lines being coupled together and plugged into the main power circuit. The regular setup man is able to complete the job, thus making it unnecessary to have an electrician or a pipe fitter.



Figure 162 shows a bin with a long spout or tray attached. This tray facilitates the grasping of very small parts. A number of parts are drawn from the bin to the tray. It is then easy to select and grasp individual parts. The ordinary gravity bin (see Fig. 160) may have a tray spout attached to it. This type of bin is superior to that shown in Fig. 162, since it does not need to be refilled so often.

**A Study of Three Types of Bins.** The results of a study<sup>10</sup> of the time to grasp machine screws (Nos. 2, 4, 8, and 12) and machine-screw nuts from various types of bins are shown in Figs. 163 and 164.

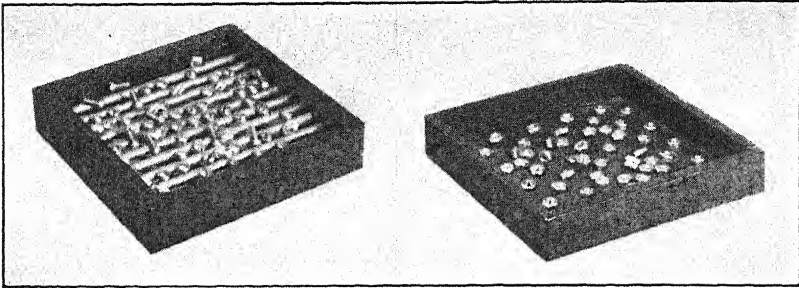


FIG. 165. Tray for positioning small machine bolts for grasping with special screwdriver attachment. FIG. 166. Tray for positioning nuts for grasping with special screwdriver attachment.

The operation consisted of selecting and grasping with the right hand a machine screw or nut from a bin, carrying it through a distance of 5 inches, and releasing it into a hole in the table top. The time for each of the motions select and grasp, transport loaded, release load, and transport empty was accurately measured.

As Table XVII shows, the bin with tray (3) required the least time to select and grasp the nuts. The hopper type bin (1) required 61 per cent more time, and the rectangular bin (2) required 68 per cent more time than did bin 3.

Trays such as those shown in Figs. 165 and 166 are used to position parts so that they may be readily picked up with special screwdrivers or wrenches. Figure 165 shows how the body of the bolt drops down between the rods in the bottom of the tray; the head remains above the rods in position to be grasped with the special ratchet screwdriver wrench shown in Fig. 215-B. The tray shown in Fig. 166 is used to keep nuts in position for grasping with the special screwdriver wrench

<sup>10</sup> University of Iowa Studies in Engineering, *Bulletin* 16, p. 28, 1939; also *The Iron Age*, Vol. 19, No. 13, pp. 32-37, March 30, 1939.



shown in Fig. 215-A. An occasional jarring motion of the tray is all that is needed to cause the nuts to drop into the holes in the bottom of the tray.

**12. "DROP DELIVERIES" SHOULD BE USED WHEREVER POSSIBLE.**

The work should be arranged so that the finished units may be disposed of by releasing them in the position in which they are completed, thus delivering them to their destination by gravity. This

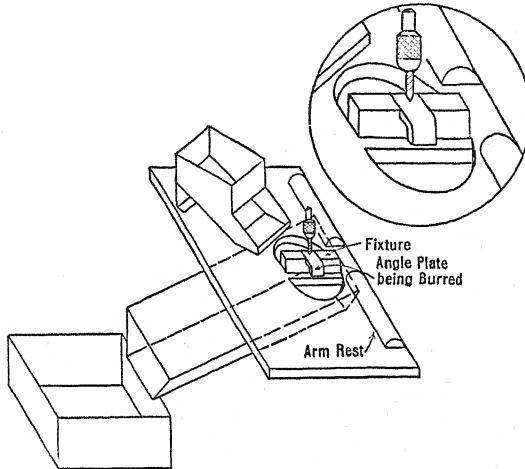


FIG. 167. Foot-operated drill press for burring small parts. Finished parts drop out of the fixture into the disposal chute by gravity.

saves time, and moreover the disposal of the objects by simply releasing them frees the two hands so that they may begin the next cycle simultaneously without breaking the rhythm. If a chute is used to carry the finished parts away, it should be located so that the parts can be released in the position in which they are finished, or as close to this point as possible.

A perfect example of this is shown in Fig. 167. The operation is burring a hole in the end of a small angle plate. The drill is fed by means of a foot pedal, and the angle plate is held in position for burring by means of a fixture. The fixture is mounted on the drill press table and extends up through a plywood board which is mounted 6 inches above the drill press table. This board serves as an auxiliary work place, making it unnecessary to cut disposal holes through the drill press table itself. Holes cut in the board on either side of the fixture lead to a disposal chute underneath.



The part to be burred is placed in the fixture, and the drill is brought down against it. This holds the part in position while it is being burred, and, when the burring is completed and the drill is raised, the burred plate drops out of the jig by gravity into the top of the disposal chute. It was economical to equip the drill press as described above because of the large quantity of burring to be done.

In the bolt and washer assembly (see Fig. 111) it was necessary to lift the finished assemblies out of the fixture and move them a few inches to one side before releasing them into the chute. A still better arrangement would have been to have the assemblies drop through the fixture by moving some sort of a trip on the bottom of the fixture which could have been actuated by a foot pedal. This arrangement, however, would have added to the cost of the fixture and was not justified in the factory where this fixture was used.

Many people do not appreciate the amount of time that may be used in disposing of finished parts. The operation shown in Fig. 68 on page 111 illustrates this point in an excellent manner. The operation is countersinking two holes on a part for a mechanical toy. The finished part is tossed into a large tote box placed on the floor at the right of the drill press. The operator carries the part such a long distance before releasing it and the velocity of her hand is so great that it actually continues to move away from her for several inches after she has released the finished piece.

A study was recently made of gauging small pins in a fixture mounted on the front edge of the table and disposing of them by tossing them into a tote box located first at a distance of 3 inches behind the fixture, then at a distance of 10 inches, and finally at a distance of 20 inches. The time required for the motions transport loaded and release load was least when the pins were tossed into the bin nearest the fixture. Eighteen per cent more time was required for the bin at 10 inches and 34 per cent more at 20 inches.

Another example of incorrect and of correct methods of disposal of parts is shown in Figs. 176 and 177 on page 266. The operation is inspecting metal bobbin spools. Spools that have such defects as bent ends, heavy paint, light paint, and poor weld are rejected. In the old method, trays for rejects were piled on the back of the inspection table, a separate tray being used for each kind of defective spool. In disposing of a reject, the inspector was required first to pick out the tray into which the particular reject should go, then to aim and throw the spool into it. The special table shown in Fig. 177 was designed for the improved method. Four openings for rejects are located along the edge of the table to the left of the working area.



The inspector soon memorizes the location of these openings and can quickly dispose of the reject in the proper place. In an analysis of this inspection operation preparatory to redesigning the table, it was found possible to classify all rejects into four groups instead of six as was formerly thought necessary. The improved method of inspection permits the inspector to do *twice* as much work per day as was formerly possible.

**13. MATERIALS AND TOOLS SHOULD BE LOCATED TO PERMIT THE BEST SEQUENCE OF MOTIONS.**

The material required at the beginning of a cycle should be placed next to the point of release of the finished piece in the preceding cycle. In the assembly of the bolt and washers (see Fig. 111 on page 196), the rubber washers were in bins located next to the chute into which the assemblies were disposed as the last motion of the previous cycle. This arrangement permitted the use of the two hands to best advantage at the beginning of the new cycle.

The position of the motion in the cycle may affect the time for its performance. For example, the time for the motion transport empty is likely to be longer when it is followed by the motion select than when it is followed by a well-defined motion such as a grasp of a pre-positioned part. The reason for this is that the mind begins to select during the transport empty. When the motion transport loaded is followed by a position motion it is slowed down by the mental preparation for the position. The time for the motion grasp is affected by the hand velocity preceding the grasp. A satisfactory sequence of motions in one kind of work may aid in determining the proper sequence in other types of work.

Since the improved method of shirt finishing in a laundry shows the application of a number of other principles of motion economy in addition to the one being described here, this operation is presented in some detail.

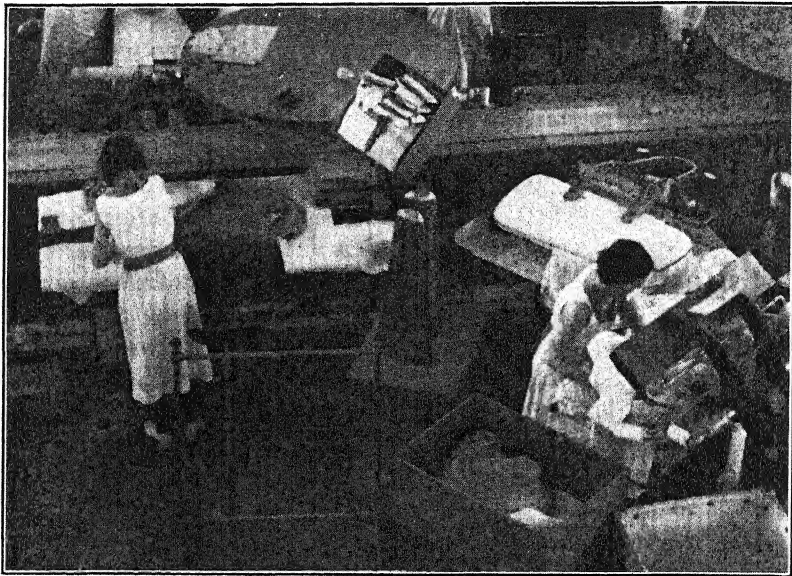
**Shirt Finishing in a Laundry.** Ironing a shirt involves considerable hand labor and illustrates a type of work that has been considered difficult to improve. The ironing operation in a laundry is ordinarily done by two persons, the ironer and the finisher. The American Institute Laundry has carefully investigated the work of the finisher and has devised a new method<sup>11</sup> of performing the operation with the re-

<sup>11</sup> R. E. Smith and W. A. Reinhard, "A Shirt Finishing Method," Laundry-owners National Association, *Service Bulletin* 46, pp. 1-7, March 25, 1936. Also, "Motion Camera Uncovers 34 Per cent Savings," *Factory Management and Maintenance*, Vol. 94, No. 11, pp. 46-47, November, 1936.



sults that the time for the complete cycle of finishing has been reduced 34 per cent and the production rate has been increased from 35 to 55 shirts per hour. Some 15,000 people are employed in the laundries of this country on this single operation.

The *ironer* operates two machines (see Figs. 168 and 169) on which she irons the collars, cuffs, fronts, and backs of the shirts. After



*Courtesy of Factory Management and Maintenance*

FIG. 168. Layout of the work place showing the position of the ironer and the finisher. This is the improved method.

completing this part of the work she pulls the sleeves over the steam-heated "sleeve" which irons the sleeves.

The *finisher* removes the shirt from the sleeve, puts it on the table, irons the yoke and the sleeves around the cuffs and shoulders, folds the shirt around a cardboard, and places a paper band around the finished shirt.

It should be remembered that it is the work of the second operator, the shirt finisher, that is being considered here.

**Old Method of Shirt Finishing.** The old method of finishing was done in the following manner. The operator removed the shirt from the sleeve at her right (see Figs. 168 and 169), turned the collar, buttoned the collar button, and placed the shirt on the table. She then straightened the yoke of the shirt, dampened the various parts of the



yoke, and ironed them. This sequence was repeated for the right shoulder and sleeve, and for the left shoulder and sleeve. The shirt was then turned over and the above process was repeated.

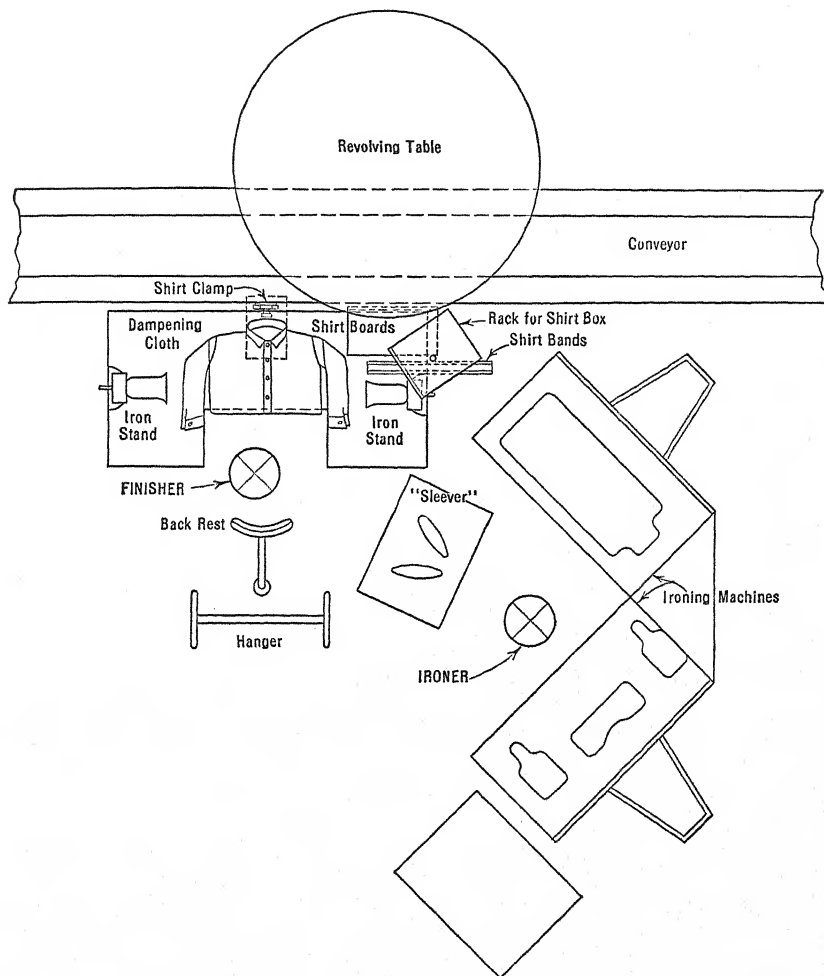


FIG. 169. Layout of the work place showing the arrangement of the finisher's table.

The shirt was then folded around a cardboard stiffener and a band placed around the shirt. The first column in Table XVIII shows the time required for each group of elements in finishing a shirt by this old method.



**Improved Method of Shirt Finishing.** The following changes were made in the layout of the work place before the new method was put into effect. A recess cut in the front of the table allows the tails to drop out of the way. This also permits the shirt to be placed flat on the table, front up, with the sleeves, neck, and shoulders forming a semicircle around the operator (see Figs. 168 and 169). The table height is adjustable, and the back legs of the table are longer than the front so that the work is brought closer to the operator, thus reducing back strain. It was found impracticable to seat the operator, but a back rest was provided and may be used during part of the cycle, providing a change of position, support for the back, and rest for the operator's feet.

A 3½-pound cordless electric iron is used instead of a 6-pound one. A stand for the iron is placed on each side of the work place, and special contacts on each stand allow the iron to heat between "uses." These two stands permit the operator to put down the iron on the side of the work place where she finishes with it, and from which she may take it most conveniently in beginning the next ironing operation.

A clamp located on the back of the table is dropped down on top of the shirt just below the collar, thus holding the shirt firmly in place while it is being folded around the cardboard stiffener.

The instruction sheet given below lists in sequence each step in the improved method of shirt finishing. The directions are stated in terms of the operator's left and right side as she faces the table.

#### INSTRUCTION SHEET

1. Make one-quarter turn to right and take shirt off sleeve.
2. Make one-quarter turn to left and face table.
3. Turn collar. (Bring collar to body to help curve.)
4. Button collar button.
5. Partly set collar by holding shirt away from body. (Operator uses back rest for elements 1 to 5.)
6. Grasp sleeves approximately 2 inches from each shoulder seam, take one step forward and lay shirt on table, front of shirt up (using elbows with a forward motion to make gussets fall alongside body of shirt). (See Fig. 169.) Sleeves will fall in this position approximately 50 per cent of the time.
7. Button third button.
8. Set collar and smooth shirt front if necessary.
9. Grasp dampening cloth, which is on left side of table. (Dampening cloth has remained in this position from previous operation.)
10. Dampen front of shirt from left to right at the following points:
  - (a) Left gusset, shoulder seam, yoke.
  - (b) Right yoke, shoulder seam, gusset. (If the sleeves do not fall in proper position on table in element 6, the operator does not correct the position of that particular sleeve until she is ready to dampen it.)



11. Drop dampening cloth on upper right side of table.
12. Grasp iron, which is on right side of table. (Iron has remained in this position from previous operation.)
13. Iron front of shirt from right to left at points previously dampened in element 10.
14. Place iron on stand on left side of table. *Note:* If collar support is used, it should be inserted at this point or before element 9.
15. Cross hands, grasp the left shoulder seam with the right hand and the right shoulder seam with the left hand.
16. Take a half step back from table and uncross hands, thereby turning over the shirt.
17. Take one-half step forward and lay shirt on table with back up, using same motions as described in element 6.
18. Grasp dampening cloth, which is on the right side of table.
19. Dampen from right to left the same points as were dampened on the front of the shirt, that is, right gusset, shoulder seam, etc.
20. Drop dampening cloth on left side of table.
21. Grasp iron on left stand and iron, from left to right, the same area as dampened in element 19. (Notice that motions on back of shirt are similar to those on front, thus building rhythm in operation.)
22. Place iron on right stand.
23. Grasp shirt board on right side of table and place in position on back of shirt. (Notice that shirt does not have to be moved on table for folding.)
24. Grasp left cuff in left hand and right cuff in right hand; make a half turn with each cuff to straighten out sleeves, then bring them together approximately in the center of the shirt board, about 8 to 10 inches above board.
25. Make a "Z" fold with the sleeves, keeping both cuffs together. (Notice that both hands are used in this folding operation.)
26. Bring shoulders one at a time over shirt board.
27. With left hand hold both shoulders in place, and with right pull down shoulder clamp.
28. Straighten out shirt fold on board, and bring shirt tail over board, removing clamp.
29. Reach for shirt band on upper right-hand side of table (see Fig. 169) and at the same time lift bottom of shirt up with left hand and slide shirt band under shirt with right hand.
30. Release shirt, bring both ends of shirt band together, fasten.
31. Turn shirt over for inspection. Place shirt in box on right side of table. (See Fig. 169.)

In the old method much time was used in carrying, turning, laying down, and adjusting the shirt. Also, there were many repetitions of the dampening and ironing elements. In the new method the shirt is placed on the table in the correct position for ironing the entire shirt on one side. The operator then takes the dampening cloth from its position on the left side of the table and, progressing across the shirt from left to right, dampens all necessary points. She releases the cloth on the right side of the table and grasps the iron. Working across the shirt from right to left, she irons one entire side of the shirt, putting the



iron down on the stand at the left of the work place. The operator then turns the shirt over by crossing her arms and grasping opposite shoulders of the shirt with her hands. A quick sweeping motion of uncrossing the arms turns the shirt over. The operator then repeats the dampening and ironing elements for the back of the shirt in the same manner as for the front.

**Results.** Table XVIII gives a detailed comparison of the two methods of shirt finishing. An analysis sheet listing individual mo-

TABLE XVIII  
ELEMENTS AND TIME REQUIRED FOR SHIRT FINISHING  
Time in Minutes

Elements	Methods of Shirt Finishing	
	Old	Improved
1. Reaching for shirt, turning collar, buttoning collar button, carrying shirt to table	0.178	0.1357
2. Setting collar, buttoning shirt buttons, and smoothing shirt front	0.109	0.0590
3. Picking up, laying down, or adjusting shirt in other ways to aid ironing	0.134	0.0603
4. Reaching for and moving dampening cloth to and from shirt	0.089	0.0357
5. Total dampening time	0.217	0.1798
6. Reaching for and moving iron to and from shirt	0.121	0.0367
7. Total ironing time	0.410	0.3300
8. Folding shirt	0.359	0.2130
9. Carrying shirt to box	0.029	0.0310
Total Time	1.646	1.0812
Production Rate—Shirts per Hour	36.45	55.5

tions shows that 242 motions were used by the right hand in finishing one shirt by the old method whereas but 114 motions appear on the possibility chart of the improved method.

**Uniform Finishing in a Laundry.** The University of Iowa Laundry processes over 4 million pounds of laundry per year. This in-



cludes laundry from the university hospitals, dormitories, and dining rooms.

Since nurses' and doctors' uniforms account for approximately 50 per cent of the garments that require hand finishing, these garments were the logical ones on which to make improvements in ironing methods. Roscoe C. Richards undertook to improve the method as a project in an industrial engineering course.

In the original method the conventional ironing board was used (see Fig. 170), and much time was consumed in carrying, turning, laying down, and adjusting the uniform. Also there were many repetitions of the dampening and ironing elements.

The improved ironing table for finishing shirts described on page 256 was tried for uniforms and was found unsatisfactory. However, by using this table and by designing a small oval ironing board (see Fig. 171) which was supported on an arm attached to the main table, it was possible to improve greatly the method of finishing uniforms. The small oval ironing board was used for finishing the shoulders, waist seams, and collar.<sup>12</sup>

The production rate on finishing fairly simple nurses' uniforms was 15 uniforms per hour using the old method. When the improved method was used, the operator could finish 25 per hour, an increase in output of 66 per cent.

The following reasons account for this increase in output:

1. Fewer lays were required to do the same work.
2. The distance that the iron was carried was reduced from 63 feet to 16 feet per uniform.



FIG. 170. Work place for old method of finishing uniforms. Conventional type of ironing board.

<sup>12</sup> Ralph M. Barnes and Roscoe C. Richards, "A New Method of Finishing Uniforms," *Laundry Age*, Vol. 19, No. 8, October, 1939.



3. The distance the operator walked was reduced from 18 feet to 6 feet per uniform.
4. The operator was trained in the correct dampening and ironing methods, eliminating patting and excessive drying time.
5. A cordless iron was used, and a definite place was provided for the iron when not in actual use.



FIG. 171. Work place for improved method of finishing uniforms. Operator grasps dampening cloth with right hand from right side of table.



FIG. 172. Recommended method of turning over uniforms. Operator crosses arms and grasps opposite shoulders of uniform, uncrossing the arms turns over the uniform.



FIG. 173. Shoulders, waist seams, and collar are finished on the small oval ironing board. The stand and electric power connection for the iron are also shown. The cordless iron heats when not in use.

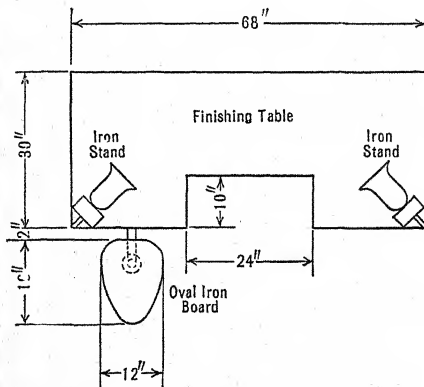


FIG. 174. Drawing showing dimensions of uniform finishing table.



**14. PROVISIONS SHOULD BE MADE FOR ADEQUATE CONDITIONS FOR SEEING. GOOD ILLUMINATION IS THE FIRST REQUIREMENT FOR SATISFACTORY VISUAL PERCEPTION.**

Visual perception may take place under such widely varying conditions that adequate provisions for seeing in one kind of work are not always most suitable for another. For example, the provisions for seeing on such very fine work as watch making would be different from those recommended for inspecting "leather cloth" or tin plate for surface defects. However, if adequate illumination is provided, seeing is made easier in every case although this may not be the complete solution of the problem. By adequate illumination is meant (1) light of sufficient intensity for the particular task, (2) light of the proper color and without glare, and (3) light coming from the right direction.

It should be borne in mind that the visibility of an object is determined by the following variables:<sup>13</sup> brightness of the object, its contrast with its background, the size of the object, the time available for seeing, the distance of the object from the eye, and other factors such as distractions, fatigue, reaction time, and glare. These variables are so related that a deficiency in one may be compensated by an augmentation of one or more of the others, provided all factors are above certain limiting values.<sup>14</sup>

The intensity of illumination falling on an object and the reflection factor of the object, or that of its background, should be considered together in providing adequate illumination. For example, the pages of a telephone directory are dark in color and the contrast between the printed letter and the page is not so great as that of printing on good book paper. The paper of the directory reflects only 57 per cent of the incident light, whereas the book paper reflects about 80 per cent. Two to three times as much light is required to read a telephone directory as is required to read with equal facility the same critical details of names and numbers printed with blacker ink on white book paper.<sup>15</sup> The task of sewing on very dark cloth is difficult even under the best conditions of lighting. For example, dark cloth of 4 per cent reflection factor would require 200 foot-candles to produce the same

<sup>13</sup> M. Luckiesh and F. K. Moss, "The Applied Science of Seeing," *Transactions of the Illuminating Engineering Society*, Vol. 28, p. 846, 1933.

<sup>14</sup> M. Luckiesh and F. K. Moss, "The Human Seeing-Machine," *Journal of the Franklin Institute*, Vol. 215, No. 6, p. 647, June, 1933.

<sup>15</sup> M. Luckiesh, "Seeing and Human Welfare," Williams & Wilkins, Baltimore, Md., p. 85, 1934.



brightness as 10 foot-candles on white cloth.<sup>16</sup> A knowledge of this point suggests the use of greater intensity of illumination or lighter background for work with objects with a low reflection factor or for very fine work. The size of the image of the object falling on the retina of the eye must be sufficiently large to allow adequate discrimination of the details. This factor requires greatest consideration in very fine work. An increase in the illumination on the object, or an increase in the contrast between the object and its surroundings, produces the same effect, within limits, as a decrease in the distance between the eye and the object.

**Relief of Eyestrain on Fine Assembly Work.** The following case<sup>17</sup> shows the changes that may be made to improve the seeing on fine

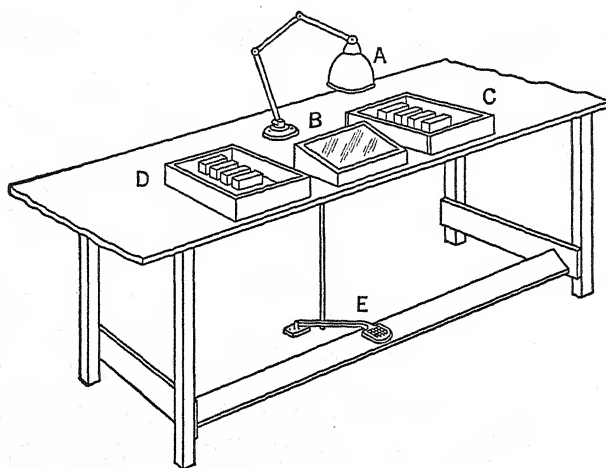


FIG. 175. Improved lighting unit. A. Adjustable lamp for direct light; B. Background light; C. Finished work; D. Work awaiting adjustment; E. Foot-operated switch for adjustable lamp.

assembly work. The operation was assembling and adjusting the parts of a delicate electric meter mechanism. The task was performed by men and boys, and about three-quarters of an hour was required for each unit. Eyestrain and fatigue were excessive, owing to the fact that on certain parts of the operation the illumination was so inadequate in relation to the smallness of the parts that the work had to be held close to the eyes.

<sup>16</sup> M. Luckiesh and F. K. Moss, "The Applied Science of Seeing," *Transactions of the Illuminating Engineering Society*, Vol. 23, p. 854, 1933.

<sup>17</sup> J. H. Mitchell, "The Relief of Eyestrain on a Fine Assembly Process," *The Human Factor*, Vol. 10, No. 10, p. 341, October, 1936.



In order to remedy this condition a rest period was introduced and improvements were made in the illumination of the work place. Figure 175 shows the improved lighting units. Because certain parts of the operation could be done best by silhouetting the mechanism against an illuminated background, a background light was placed on the work bench and was kept "on" all the time. When it was necessary to view the assembly under direct light the foot pedal was depressed, turning on the upper lamp. Tests showed that the best color for the background light was white or pale yellow and that it should be free from glare.

The effects of the rest period and of the improved illumination on six men in the experimental group over the period of the test were an improvement in the quality of the work and also an increase in output of 19.5 per cent. The rest period was included as working time in calculating hourly output.

**Use of Special Spectacles for Very Fine Work.** On certain kinds of very fine work the eye must be kept very near the object, however high the intensity of illumination may be. The constant use of the eyes on objects at such close range imposes a serious strain<sup>18</sup> on the muscles of convergence and accommodation.<sup>19</sup> Experiments show that the use of special spectacles is advisable to permit the eyes to assume their normal condition. An increase in output approximating 12 per cent has been found to result from the use of glasses on such work as mounting lamp filaments, "linking" in hosiery making, and "drawing-in" in weaving processes.<sup>20</sup>

**Time for Seeing.** Seeing can take place only after the eyes come to a stop and are focused on the object. In the process of reading a printed page, for example, the eyes do not make a continuous movement along the line, but rather move in a series of jumps or leaps. The eyes begin at the left-hand end of the printed line and progress from one fixation to the next along the line to the right-hand end of the line. The eyes then move back to the left-hand end of the next

<sup>18</sup> H. C. Weston and S. Adams, "On the Relief of Eyestrain among Persons Performing Very Fine Work," Industrial Fatigue Research Board, *Report* 49, p. iii, 1928.

<sup>19</sup> "When a near object is viewed, two muscular actions take place simultaneously, the one causing a slight rotation of the eyes inwards toward each other, thus allowing the image to fall on the same point of the retina in each eye, the other a change in the curvature of the lenses of the eyes, the object being thereby kept in focus. The former of these is known as *convergence*, the latter as *accommodation*. . . ." *Ibid.*, p. iii.

<sup>20</sup> *Ibid.*, p. 5.



line with a single smooth sweep, during which movement the eyes see nothing. The movements of the two eyes are coordinated and one cannot move voluntarily without the other. The number of movements and pauses which the eyes make in reading a line of print will vary, usually from three to seven, depending upon the length of the line, the visibility of the print, the skill of the reader, and other factors.

It is generally agreed that the optimum length of line is 3 to 4 inches and that it should not exceed 4 inches by very much. Ten-point type seems to be the optimum size, although there is some evidence to show that the optimum size may cover a considerable range.<sup>21</sup>

Fixation pauses require on the average 0.17 second. Tests show that the shortest interval of time possible for a person to see an object to gain an adequate visual impression varies from 0.07 second to 0.30 second, the average being 0.17 second.<sup>22</sup> The intensity of illumination affects the time required for seeing. "If an object of 50 per cent contrast can just be seen under a certain intensity of illumination when the time available is 0.30 second, the intensity of illumination must be trebled if it is to be visible when the time is reduced to 0.07 second."<sup>23</sup>

#### INSPECTION WORK

The provision for adequate conditions for seeing is of paramount importance in inspection work. Such work is usually highly repetitive, exacting in nature, and predominantly mental in its demands. Constant attention and almost continuous use of the eyes are required in many kinds of inspection work. Perception of a defect must be followed by instant action on the part of the inspector to reject the defective part. Some individuals are able to see smaller differences than others and to perceive the same differences with greater speed. Since reaction time and visual acuity are important elements in most inspection work it is essential that persons be selected by means of suitable tests before being employed for such work.<sup>24</sup>

**Inspection of Metal Spools.** Some practical applications are included here to show how provisions were made for adequate conditions

<sup>21</sup> M. D. Vernon, "The Experimental Study of Reading," pp. 165-166, Cambridge University Press, London, 1931.

<sup>22</sup> M. Luckiesh, "Seeing and Human Welfare," p. 96, Williams & Wilkins, Baltimore, Md., 1934.

<sup>23</sup> *Ibid.*, p. 96.

<sup>24</sup> S. Wyatt and J. N. Langdon, "Inspection Processes in Industry," Industrial Health Research Board, *Report 63*, p. 46, 1932.



for seeing. The first case is the inspection of metal bobbin spools for dents, scratches, heavy paint, light paint, and bent flanges. Since the improved method of inspection employs a number of principles of motion economy in addition to those for adequate seeing, this operation is presented in some detail.

**Original Method of Inspection.** The inspector was seated at a table as shown in Fig. 176. The spools to be inspected were placed at the inspector's left in a large steel tote box *A*. The good spools were arranged in order in the small metal tray *B* at the inspector's right. Defective spools were tossed into trays at the back of the table and directly in front of the inspector. They were classified as *C*, bent ends; *D*, light paint; *E*, overlap barrels; *F*, off-center flanges; *G*, culls; *H*, heavy paint.

**Elements of the Operation.** The inspector, turning to the tote box (previously positioned by the supply man) at her left, grasped spools with both hands and carried them to the table in front of her where she deposited them. This was repeated until a pile had been accumulated. The inspector procured an empty tray for the good spools from a pile at her right. She also positioned empty trays for various kinds of defects.

The inspector then proceeded with the inspection of the spools in the following manner:

1. She picked up one spool from the pile with the thumb and index finger of each hand, inspected the outside of flanges by looking straight down on them, tipped spools slightly, and then, by turning spools, inspected for bent ends. She turned spools end for end and repeated the above elements for the other flanges. Then she tipped spools back horizontally, and by turning spools around inspected for defects on the inside of flanges. If the spools were good she flipped them back into the palm of her hand; if a defect was found she disposed of the spool in the proper reject tray. These elements were repeated until three or four spools (depending upon the size of the spools) had been accumulated in each hand.
2. The inspector placed the spools held in her right hand in the tray of good spools at her right. She then transferred the spools accumulated in the left hand to the right hand and placed these in the tray with her right hand. During this time the left hand was idle. The inspector then moved both hands to the pile in front of her and repeated the elements in 1.



3. As tiers of good spools were built up in the tray the operator jogged the spools into position, pushing the tier over against the preceding one; or if it was the first tier, she pushed it over against the side of the tray.
4. When a tray was filled the inspector made out a ticket and placed it in the end of the tray. She then placed the tray on the back of the table where it was picked up by the supply man.

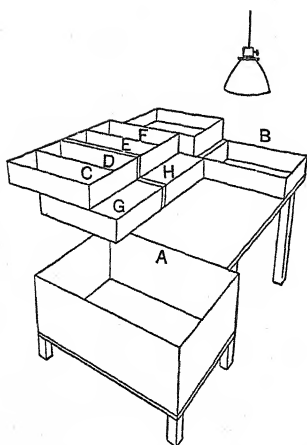


FIG. 176. Layout of work place for inspection of metal spools—old method. A. Supply of spools to be inspected; B. Good spools; C-D-E-F-G-H. Rejected spools.

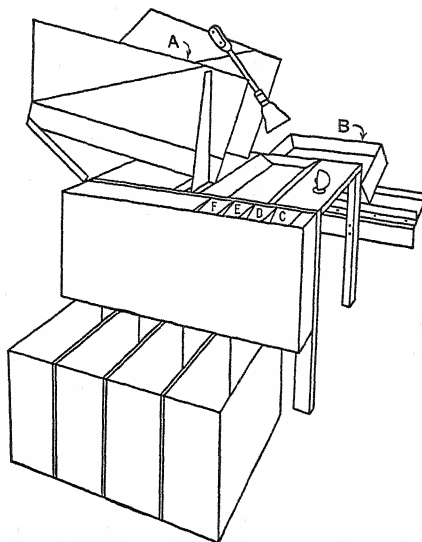


FIG. 177. Layout of work place for inspection of metal spools—improved method. A. Supply Hopper—spools to be inspected; B. Good spools; C-D-E-F. Rejected spools.

**Improved Method of Inspection.** The inspector is seated at a table as shown in Fig. 177. The spools to be inspected are placed in the hopper A, Fig. 177, by the supply man and they are fed by gravity down on the inspection table. The good spools are placed in order in the tray B at the inspector's right. This tray is tipped up at an angle and is placed at the correct height for disposing of the spools with least effort. When a defective spool is found it is placed by the left hand into one of the four openings in the top of the table at the inspector's left. These go by chute to trays on the floor. Defective spools are classified as C, bent ends; D, light paint; E, heavy paint; or F, culls.



**Elements of the Operation***Elements for Good Spools***Left Hand**

1. Pick up two spools.
2. Transfer one spool to right hand.
3. Inspect upper flange under upper light.
4. Turn spool 60°.
5. Inspect other flange in front of lower light.
6. Inspect barrel while spool is rotated between thumb and index finger (under upper light).
7. Flip spool to palm of hand.
8. Pick up one spool.

**Right Hand**

1. Pack good spools in tray.
2. Receive one spool from left hand.
3. Inspect upper flange under upper light.
4. Turn spool 60°.
5. Inspect other flange in front of lower light.
6. Inspect barrel while spool is rotated between thumb and index finger (under upper light).
7. Flip spool to palm of hand.
8. Pick up one spool.

Repeat elements 3, 4, 5, 6, 7, and 8 until there are three or four spools in each hand.

9. Transfer spools to right hand.

9. Grasp spools from left hand.

*Elements for Defective Spools*

1. When heavy paint, bent ends, or "jams" are found in elements 3, 5, or 6, reject spools to disposal chute. When light paint is found in element 3, inspect spool (elements 5 and 6) for other defects before rejecting.
2. Grasp spool from right hand and reject it.

1. Pick up another spool.
2. When a defective spool is found in right hand transfer it to left hand and get new spool.

**Auxiliary Elements**

1. Procure empty tray from pile behind inspector and position tray on table at right.
2. When tray is full make out ticket and place in end of tray.
3. Push finished tray of work to back of table ready for collection by the supply man.

**Comparison of the Two Methods of Inspection.** The improved method of inspection is superior to the old method in the following ways:

1. Two lights on the new table furnish illumination for inspection so that it is necessary only to turn the spools 60 degrees to inspect both ends. In the old method, using but one light, it was necessary to turn the spools end for end or 180 degrees. The intensity



of illumination has been greatly increased so that now at the point of inspection there is 150 foot-candles. The bulbs are completely shielded to prevent glare.

2. The work of the two hands has been so arranged that neither hand has practically any idle time during the cycle.
3. The supply of spools is placed in the hopper by the supply man, and they are fed by gravity (occasionally pulled down by the inspector with a hook) down to the inspection table. This saves the time of lifting the spools from the tote box to the table as required in the old method.
4. The rejected spools are dropped in openings located conveniently near the working position of the hands. In the old method the inspector had to toss the spools into trays piled in front of her. This motion required more time and more physical effort than the new method.
5. The tray for receiving good spools is located at the proper height and is tipped up at a convenient angle.
6. The tray of finished work rests on a metal track and may be easily shoved to the back of the table, from which the supply man removes it. The inspector is not required to lift full trays of work.
7. Inspectors are now given a 5-minute rest period at the end of each hour, and they are enthusiastic about them. Formerly one 5-minute rest period was provided in the morning and one in the afternoon. The inspectors are paid at their regular hourly base rate for the rest periods. For the remainder of the day they are paid a wage incentive in the form of a premium for all production above standard.
8. Arm rests on the front of the table tend to steady the hands and reduce fatigue. Chairs are carefully adjusted to fit the individual inspector.

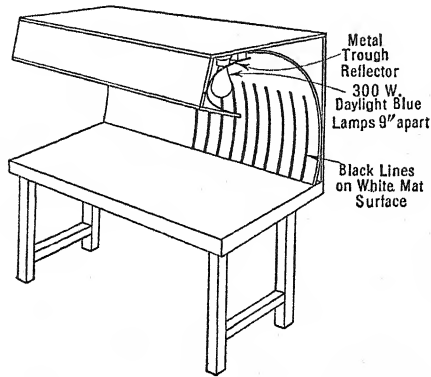
**Training Inspectors.** Considerable study was required in designing the new table and in determining the proper procedure for the inspection elements themselves. After the most satisfactory method was worked out the inspectors were carefully trained. Slow-motion pictures were used to show the sequence of motions, and only after very careful and persistent training were the inspectors able to do the work in the proper manner and thus accomplish the expected amount of work per day.

**Savings.** The inspectors can now inspect *twice* as many spools per day as formerly, and they apparently do it with less eyestrain and



fatigue. Less than half the floor space is required for the inspection work and the department has a neater appearance than formerly. The quality of inspection has not suffered by the increased output per inspector. The new tables cost less than \$25 each.

**Inspection of Polished Surfaces.** The inspection of highly polished surfaces for surface defects cannot be done under ordinary artificial lighting systems because the glare produced on the shiny surfaces reflects the light into the eyes of the inspector. The special lighting



*Courtesy of Westinghouse*

FIG. 178. Special lighting booth for the inspection of products with polished surfaces.

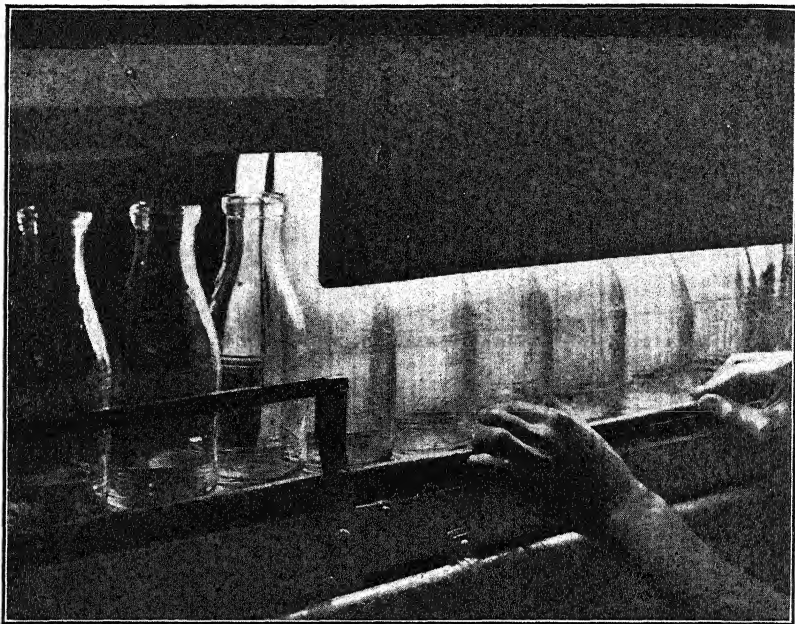
booth shown in Fig. 178 was devised for such work.<sup>25</sup> The curved background is painted a dull white with black parallel stripes running vertically at one end. This lighting unit serves two purposes. The reflection of the stripes on sheet material that is supposed to be smooth and flat aids in revealing uneven or irregular surfaces, and the portion of the lighting unit having no stripes gives a high-intensity indirect light which is effective for disclosing scratches, holes, thin plating, and other similar surface defects. Dents and rough spots also show up well in reflected light.

**Inspection by Transmitted Light.** Products made of transparent or translucent material may be inspected by transmitting the light through the product. Broken fibers, knots, and other defects in cloth are easily detected; bubbles, cracks, and foreign material in glass and cellulose show up when transmitted light is used for inspection.

<sup>25</sup> J. J. McLaughlin, "Tailor-Made Local Lighting," *Mill and Factory*, Vol. 19, No. 5, p. 56, November, 1936.



Figure 179 shows an example of transmitted light for inspecting milk bottles for dirt, cracks, grease, and pieces of broken glass. In a trough just above the moving belt on which the washed bottles pass on their way to the bottling machines, 200-watt bulbs are installed base to base. Approximately 150 foot-candles of light is present on the belt surface. The back portion of the inspection surface is painted



*Courtesy of Westinghouse*

FIG. 179. Inspection of milk bottles by transmitted light.

white in order to reveal black defects, and the conveyor belt is black in order to aid in detecting pieces of broken glass which might be resting on the bottom of the bottle. An operator can inspect bottles at the rate of 128 per minute as they pass by on the conveyor.

**Adjusting Electric-Fan Blades.** After the blades for an electric fan have been formed and assembled to the hub it is necessary to bend or adjust the blades until they are true. The original method of doing this was to mount the fan blade unit on a vertical spindle attached to the work bench and then twist each blade until the two edges just cleared pins or gauges mounted on the bench.

An improved method was developed by which a beam of light was passed over one blade and onto a white screen on which were placed



black lines to indicate the correct position of the top and bottom edges of the fan blade. The operator merely twisted the blade until the shadow came within the two black lines on the screen and then proceeded to adjust the next blade. A booth with three sides and a top was placed on the work bench so that a dark shadow would be cast on the screen by the fan blade. An operator using this improved method can now do five times as much work as formerly.

**15. THE HEIGHT OF THE WORK PLACE AND THE CHAIR SHOULD PREFERABLY BE ARRANGED SO THAT ALTERNATE SITTING AND STANDING AT WORK ARE EASILY POSSIBLE.**

The worker should be permitted to vary his position by either sitting or standing as he prefers.<sup>26</sup> Such an arrangement enables the individual to rest certain sets of muscles, and a change of position always tends to improve the circulation. Either sitting or standing for long periods of time produces more fatigue than alternately sitting or standing at will. In many kinds of work provision can easily be made for this sitting-standing combination. So important is this from the point of view of health that some states have laws requiring that the work place be arranged to permit either sitting or standing.

**SEATS AND WORK TABLES.** As far as, and to whatever extent, in the judgment of the commission, the nature of the work permits, the following provisions shall be effective: Seats shall be provided at work tables or machines for each and every woman or minor employed, and such seats shall be capable of such adjustment and shall be kept so adjusted to the work tables or machines that the position of the worker relative to the work shall be substantially the same whether seated or standing. Work tables, including cutting and canning tables and sorting belts, shall be of such dimensions and design that there are no physical impediments to efficient work in either a sitting or a standing position, and individually adjustable foot rests shall be provided. New installations to be approved by the commission.<sup>27</sup>

Although it would be preferable to have the height of the work place and the chair fit the particular operator who has to use it, this cannot always be done. It may be necessary in many cases to make the benches of such height that they will be most suitable for the average worker.

The height of the worker's elbow above the standing surface is commonly taken as the starting place for determining the proper

<sup>26</sup> "First Principles of Industrial Posture and Seating," New York Department of Labor, *Special Bulletin* 141, p. 2, January, 1926.

<sup>27</sup> "Seating of Women and Minors in the Fruit and Vegetable Canning Industry," California Industrial Welfare Commission, *Bulletin* 2a, p. 3, February, 1928.



height of the work place and the chair. The Industrial Welfare Commission of California has found that the height of the average worker's elbow above the standing surface is 40 inches for women (for men this would be 2 or 3 inches higher) and that a large percentage of the workers will not vary  $1\frac{1}{2}$  inches from this measurement.<sup>28</sup> A study<sup>29</sup> of 200 factory girls made in England shows that the mean height for the group was 39.5 inches and 70 per cent of the group fell within 1.5 inches variation.

With 40 inches taken as the average elbow height of the female workers (the range being from 34 to 45 inches) and with the hand allowed to work 1 to 3 inches lower than the elbow, the average height of the working surface should be 37 to 39 inches. The chair should be 25 to 31 inches high, depending upon the proportions of the individual. With such table and chair heights the worker is permitted either to stand or sit at work, with the elbow and the hand maintained at the same position relative to the work place.

#### **Space between Top of Seat and Under Surface of Bench Top.**

The work place should be constructed to permit plenty of leg room for the worker. Braces, shafts, and other obstructions under the work place often interfere with the natural position of the worker and so cause poor posture and discomfort. Such obstructions should not be permitted. The work bench should preferably be not over 2 inches thick and there should be 6 to 10 inches of space between the top of the chair seat and the under surface of the bench.

A bench 37 inches high will be too high for the short person, but this can be corrected by placing a rack of the proper height on the floor for the worker to stand on. For the tall worker a small rack or platform can sometimes be placed on top of the bench to raise the height of the work place. Where this cannot be done the tall worker is handicapped while standing at work, but, of course, this is not necessarily true when she is seated.

In some kinds of work it is necessary to have equipment or material containers mounted on top of the work bench. This has the effect of adding to the "thickness" of the bench. A work place more than 5 inches thick cannot ordinarily provide a comfortable sitting-standing position for the worker. The Industrial Welfare Commission of California was confronted with the problem of specifying a standard work place for their fruit and vegetable canning industries where a pan

<sup>28</sup> *Ibid.*, p. 3.

<sup>29</sup> L. A. Legros and H. C. Weston, "On the Design of Machinery in Relation to the Operator," Industrial Fatigue Research Board, *Report* 36, p. 9, 1926.



3 inches high was placed on top of the work table. The work place<sup>30</sup> which their studies led them to recommend is shown in Fig. 180. Considering the average elbow height as 40 inches above the floor and allowing for the hands to work at a position 1 inch lower than the elbow,

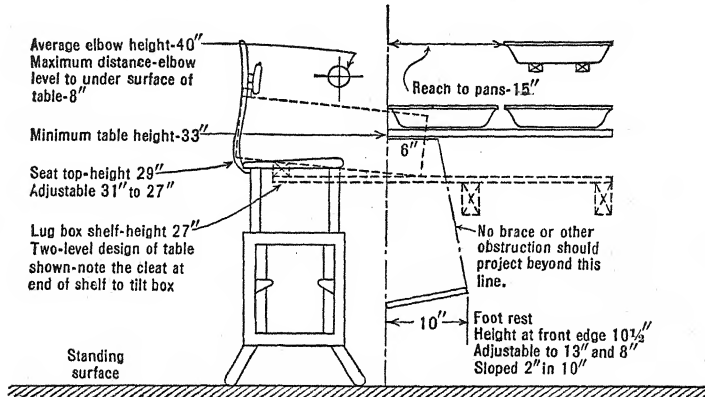


FIG. 180. Cutting table dimensions. Table designed by the Industrial Welfare Commission of California.

and further allowing 3 inches for the height of the ordinary fruit pan, we see that the top of the work bench should be about 36 inches above the standing surface in this case.

As Fig. 180 shows, a foot rest is attached to the bench, and a chair that can be adjusted for height is specified. This arrangement permits the worker to sit or stand while working and still maintain the same relative position of the elbow.

The minimum table height for a comfortable position is determined by another limiting factor. A distance of not more than 8 inches between the elbow height and the under side of the table can be permitted if a restful position is to be maintained. A distance much greater than this interferes with the natural position of the knee. Using this distance of 8 inches as the limiting factor and

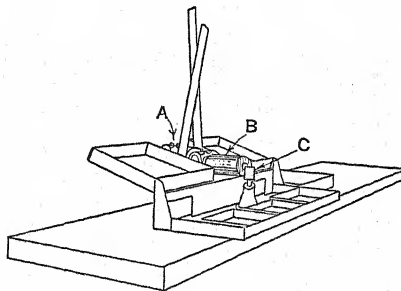


FIG. 181. Bench lathe cut in half to permit sitting or standing at work. This lathe is used for the assembly of hard rubber syringe parts.

<sup>30</sup> California Industrial Welfare Commission, *Bulletin 2a*, p. 10.



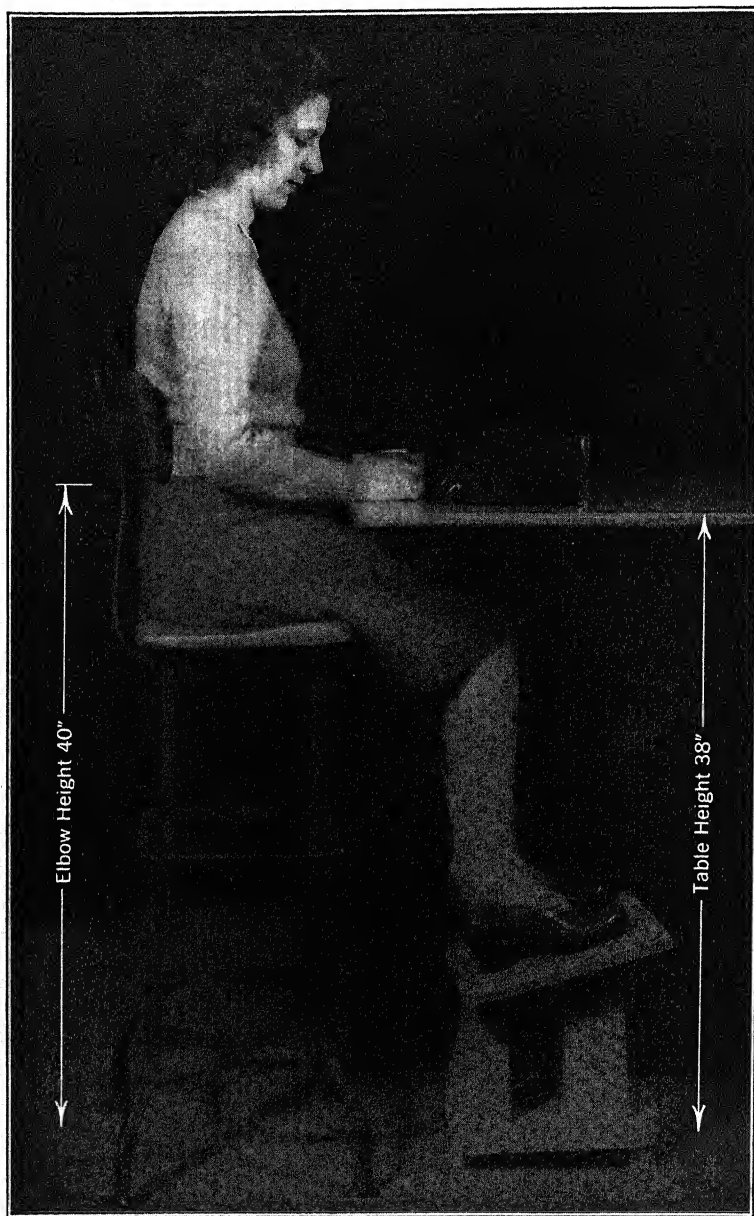


FIG. 182. For greatest comfort the work place and the chair should be so arranged that alternate sitting and standing at work are easily possible. For most kinds of work the top of the work bench should be 1 to 3 inches lower than the worker's elbow.



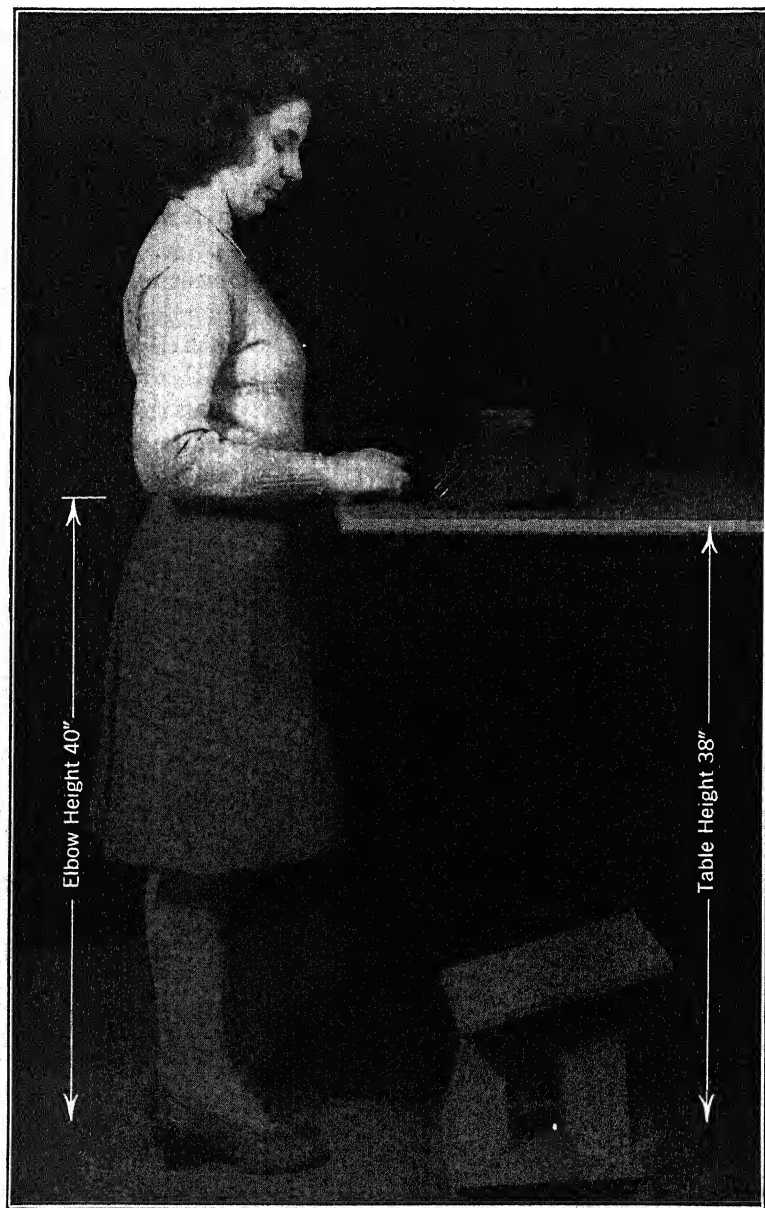


FIG. 183. It is possible to adjust chair and table heights to permit the elbow and the hand to maintain the same position relative to the work place whether sitting or standing.



allowing 1 inch for the thickness of the bench, we find the minimum height of the top of the bench to be 33 inches.

In some plants bench lathes have been cut in half (see Fig. 181) and mounted on the bench with the axis of the spindle perpendicular to the front edge of the bench. This arrangement permits sitting-standing and facilitates working with both hands.<sup>31</sup>

**Arm Rest.** Occasionally the work is of such a nature that it is desirable to have arm rests provided at the work place. Arm rests are most effective on work that requires little movement of the forearms with the hands working at approximately the same position, often at some distance from the body, for long periods of time. Light drilling, tapping, and reaming operations are frequently of this type. On such work it is restful to have padded, metal, or wood arm rests placed on top of, or at the edge of, the work bench in a position to support the forearm. The arm rests need not interfere with the necessary working movements of the arms or hands. Figure 167 on page 251 shows such an arm rest.

**Foot Rest.** When high chairs are used a foot rest should be provided. This foot rest should preferably be attached to the floor or the bench but, even though less desirable, it may be fastened to the chair. The foot rest should be of ample width and depth to permit the entire bottoms of both feet to rest on it and allow for some movement. It usually requires a depth of 12 inches or more. The absence of a foot rest forces the worker to hook the heel of his shoe over the rung of the chair (see Fig. 135), or else let the feet dangle in the air, both of which positions are uncomfortable.

**16. A CHAIR OF THE TYPE AND HEIGHT TO PERMIT GOOD POSTURE SHOULD BE PROVIDED FOR EVERY WORKER.<sup>32</sup>**

The following statements are included here to explain clearly just what is meant by good posture.

*Good standing posture* is one in which the different segments of the body—head, neck, chest, and abdomen—are balanced vertically one

<sup>31</sup> W. R. Mullee, "Motion Study Is Safety's Partner," *National Safety News*, Vol. 34, No. 5, p. 23, November, 1936.

<sup>32</sup> New York State Labor Law, Section 146, Subdivision 3: "No female under sixteen years of age shall be employed in any capacity which compels constant standing."

Section 150: "A sufficient number of suitable seats, with backs where practicable, shall be provided and maintained in every factory, mercantile establishment, freight or passenger elevator, hotel and restaurant for female employees who shall be allowed to use the seats to such an extent as may be reasonable for



upon the other so that the weight is borne mainly by the bony framework and a minimum of effort and strain is placed upon the muscles and ligaments. In this posture under normal conditions the organic functions—respiration, circulation, digestion, etc.—are performed with least mechanical obstruction and with greatest efficiency.

*Good sitting posture.* The thing which should always be insisted upon in the use of the body in any way is that the body should be kept straight from the hips to the neck and should not be allowed to flex or bend at the waist line. Any position which allows this bending lowers the vitality of the individual, leads to strain of the back, and naturally lessens the efficiency of the worker.

The most frequent violation of the good sitting posture occurs when the individual slumps in his chair or assumes a sideways slouch, both of which are fatiguing and impair the health.

When the worker is seated, the chair should aid and not hinder him in maintaining good posture. A good chair should have the following features:

1. The chair should be adjustable in height so that it may be readily fitted to the particular individual who is to use it. Non-adjustable chairs may be obtained in different sizes and issued to the workers according to their height. Such chairs are not generally considered as practical as the adjustable type. The chair should be adjusted to a height that permits the worker to sit comfortably with both feet resting on the floor or the foot rest. (See Fig. 184.)
2. The chair should be rigidly built, preferably of steel frame with wood seat and back. It is important that a wood seat and back be provided since wood is more comfortable than metal. The edges of the seat and back should be rounded so that no sharp edges can cause discomfort and impede the circulation. Swivel chairs and chairs with casters are not recommended for factory work unless absolutely necessary. The easy movement of such chairs tends to cause unsteadiness while being used. This is particularly

the preservation of their health. In factories, female employees shall be allowed to use such seats whenever they are engaged in work which can be properly performed in a sitting posture. In mercantile establishments, at least one seat shall be provided for every three female employees and if the duties of such employees are to be performed principally in front of a counter, table, desk or fixture, such seats shall be placed in front thereof, or if such duties are to be performed principally behind such counter, table, desk or fixture they shall be placed behind the same."



noticeable if the work requires some muscular effort. The chair may be provided with smooth metal "sliders" which permit the operator to shove it back out of the way without disturbing his work when he wishes to work standing.

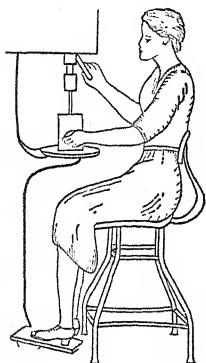


FIG. 184. A well-designed and properly adjusted back rest helps to hold the spine erect by relieving the strain on the back muscles.

3. The chair seat should be form fitting. A saddle seat permits the weight of the body to be evenly distributed and so promotes comfort. The front edges of the seat should be well rounded. (See Fig. 185.) For normal work the front edge of the chair should be approximately 1 inch higher than the back edge. When the person works leaning forward, the seat of the chair should be approximately flat. The seat should be of sufficient width to accommodate the body—16 to 17 inches is none too wide. However, the seat should not be over 13 or 14 inches in depth. The shallow seat permits the body to bend at the hip when leaning forward, whereas a deep seat tends to prevent this and to cause the body to bend at the waist line, putting a curve in the spine and disturbing the posture.

The deep seat also tends to cut off the circulation of the blood through the underside of the thighs near the knee.

4. A back rest should be provided to support the lower part of the spine. (See Fig. 184.) To do this the chair should not have a horizontal cross slat or bar lower than 6 inches above the seat. The body should sit well back on the seat so that the back rest can support the small of the back. The lower edge of the back should be 6 to 7 inches above the seat, depending upon the individual. The back rest may be 3 to 4 inches wide and 10 to 12 inches broad. The back rest may be small and yet give satisfactory support. It can be so designed that it will not interfere with the movements of the individual's arms while working. It is important that the back rest be adjustable so that it may be fitted to the worker's body. When the worker leans forward while working, the chair back is of no use; however, the



FIG. 185. The chair seat should be form-fitting and the front edges should be well-rounded.



worker can use it while resting and it serves a very valuable purpose in being there for momentary relaxation.

In the finishing of shirts in the laundry it was found to be impracticable for the operator to work seated; however, a back rest was provided and could be used by the operator during a part of each cycle. (See Fig. 169.)



## CHAPTER 17

### PRINCIPLES OF MOTION ECONOMY AS RELATED TO THE DESIGN OF TOOLS AND EQUIPMENT

#### **17. THE HANDS SHOULD BE RELIEVED OF ALL WORK THAT CAN BE DONE MORE ADVANTAGEOUSLY BY A JIG, A FIXTURE, OR A FOOT-OPERATED DEVICE.**

From an observation of the tools and fixtures usually found in the factory one is convinced that most tool designers do not give much thought to the principles of motion economy when they design them.<sup>1</sup> In most cases the fixtures are made for hand operation only, whereas foot-operated ones would more advantageously permit the operator to have both hands free to perform other motions.

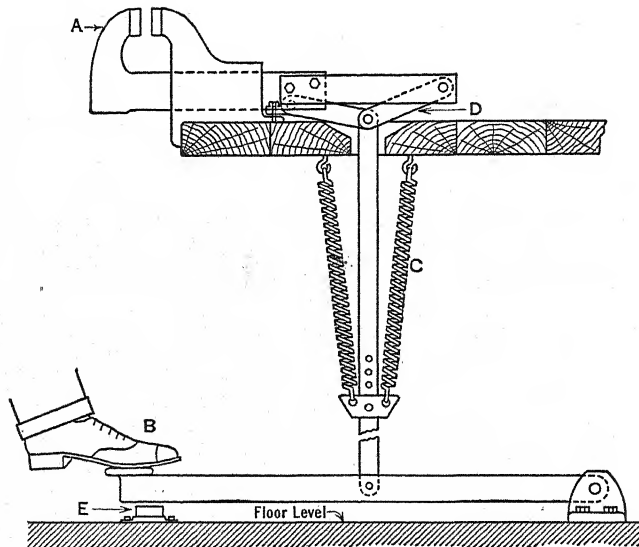


FIG. 186. Foot-operated bench vise.

<sup>1</sup> A. H. Mogensén, "Motion Study in the Design of Production Equipment," *Product Engineering*, Vol. 3, No. 8, pp. 313-316, August, 1932; also "Motion Study: Why Has the Designer Ignored It?," *Mechanical Engineering*, Vol. 55, No. 12, pp. 727-731, December, 1933; and O. W. Habel and G. G. Kearful, "Machine Design and Motion Economy," *Mechanical Engineering*, Vol. 61, No. 12, p. 897, December, 1939.



**Foot-Operated Tools and Fixtures.** Figure 186 shows an ordinary bench vise converted into a foot-operated one. Depressing the foot pedal *B* opens the vise jaw *A*, and then the piece to be held is placed

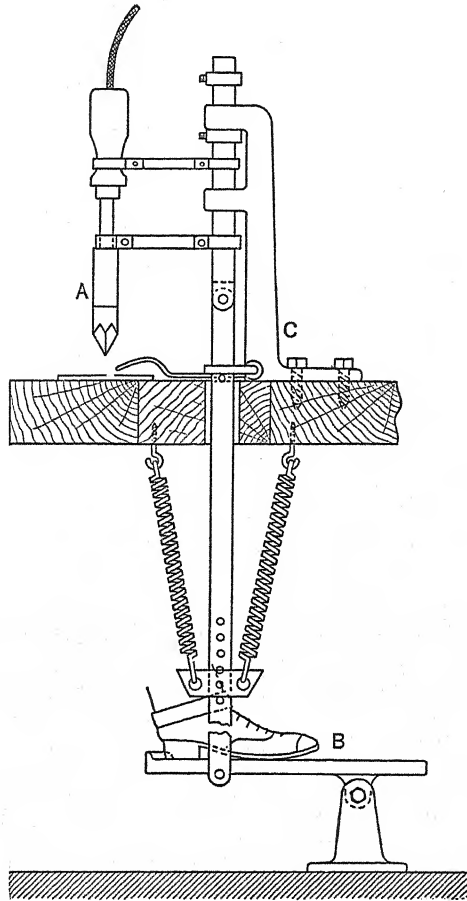


FIG. 187. Foot-operated soldering iron.

in the vise and the pedal is released. The heavy coil springs *C* close the vise, and the toggle joint *D* holds the vise in the closed position while the operation is being performed on the piece. One end of the toggle joint is linked to the stationary vise jaw and the other end is connected to an extension of the movable jaw. This type of vise was developed at the Cadillac factory and is used in a number of places



in that plant. Where greater gripping power is needed a vise may be used with a compressed-air-operated piston to actuate the vise jaws, the air being controlled by a foot-operated valve.

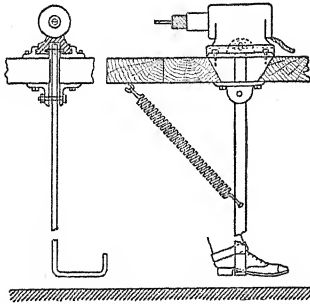


Fig. 188. Motor-driven screwdriver—foot-operated.

Hand tools can often be attached to or incorporated with a simple foot press or a modified arbor press in such a way that the tool is manipulated entirely by the foot. The electric soldering iron *A* in Fig. 187 is raised and lowered by the foot pedal *B*. After the soldered joint is made and as the iron is raised and valve *C* on the compressed air line opens, a stream of air cools the soldered joint.

One company saved 50 per cent in time on the operation of soldering a wire to the end of a flat metal electric static shield by the use of this foot-operated soldering iron.

The electric motor-driven screwdriver shown in Fig. 188 has made possible a 50 per cent saving in time on several short assembly operations. The assembly fixture, material bins, and drop-delivery chute have been omitted from the figure in order to show more clearly the linkage which permits the foot operation of the screwdriver.

Although the foot pedals shown in Figs. 186 and 187 may be satisfactory for manipulating most devices, they are not satisfactory when greater control is required, such as in feeding a small drill press. This is particularly true when very small drills are used and the problem of excess drill breakage becomes important. The pedal shown in Fig. 189 gives the operator almost as much control with the foot as with the hand in feeding the drill.

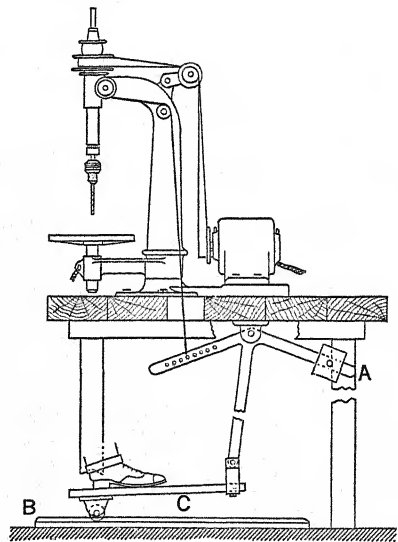


Fig. 189. Bench drill press with foot-operated feed.

The pedal, of course, frees both hands for other useful work. The linkage is clearly shown in the figure—the operator



lowers the drill by moving the pedal away from him, the weight at *A* acting to return the pedal and thus permitting the drill to rise. The roller *B* attached to the bottom of the pedal moves on the flanged metal track *C* attached to the floor. Since the weight of the foot is carried entirely by the roller and since the movement of the drill is affected only by the motion of the pedal in the horizontal plane, very accurate

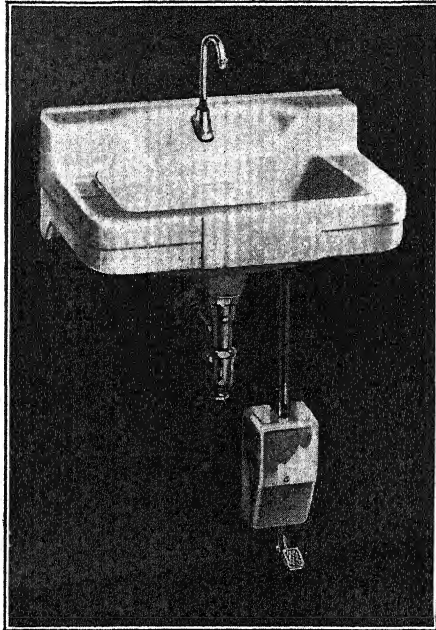


FIG. 190. Lavatory equipped with pedal valve permits free use of hands.

control is possible. The whole linkage is quite stable, enabling the operator to manipulate the drill press with ease and precision.

It is sometimes possible to use two foot pedals to actuate different parts of a jig, fixture, or machine. Such a setup should cause no difficulty for the operator. We are all familiar with the fact that the automobile has three and often more pedals which the driver manipulates with ease and often while traveling at high speed.

All modern hospitals now have the lavatories equipped with pedal valves which permit free use of both hands and also prevent their contamination. (See Fig. 190.)

**Opening a Shipping Carton.** The operation shown in Fig. 191 consists of opening up a flat shipping carton and folding over the bottom flaps preparatory to filling it with boxes of breakfast cereal in the



packing room of the cereal factory. Cartons are delivered to the packing table and are stacked horizontally as shown in Fig. 191A.

**Improved Method.** This operation is the same as the one described above. However, the cartons are stacked on the table vertically (see

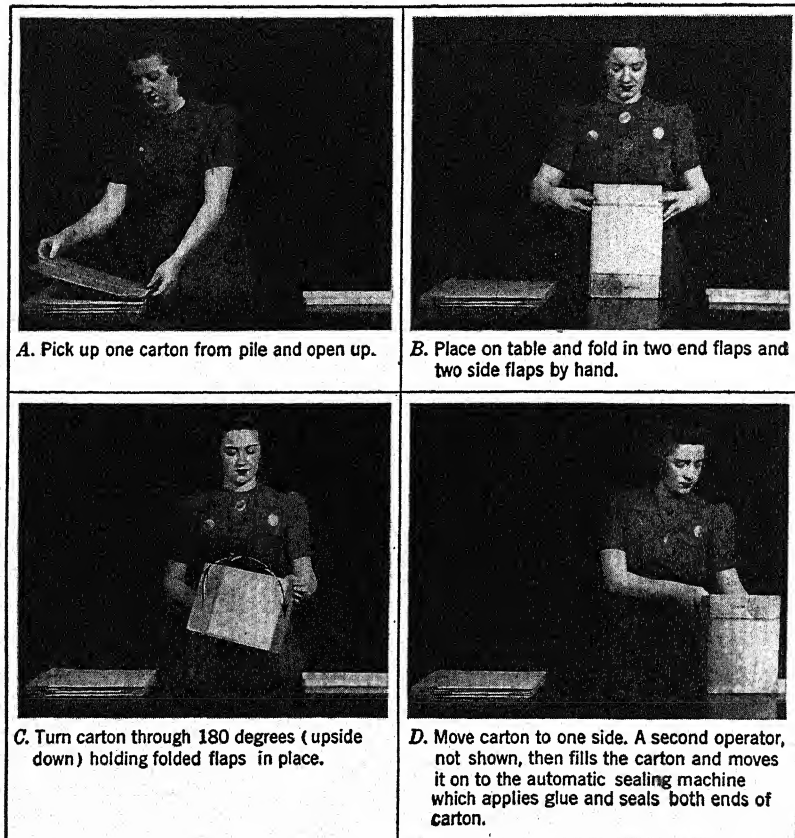


FIG. 191. Opening shipping cartons—old method.

Fig. 192A) instead of horizontally. A simple fixture, designed by E. H. Hollen, is made of heavy wire and is used to aid the operator in folding in the two end flaps and the two side flaps.

Since the time required to open up the carton and fold in bottom flaps is so short using this improved method, the same operator who does this also fills the carton. Therefore the carton is filled with boxes of cereal in position D, Fig. 192. The carton is then moved on to the automatic sealing machine which applies glue and seals both



ends of the carton. Notice that the fixture contains no moving parts, and it was made from 20 feet of No. 9 gauge wire and a piece of board at a total cost of a few dollars. Using this fixture, the operator can open cartons in less than half the time required when

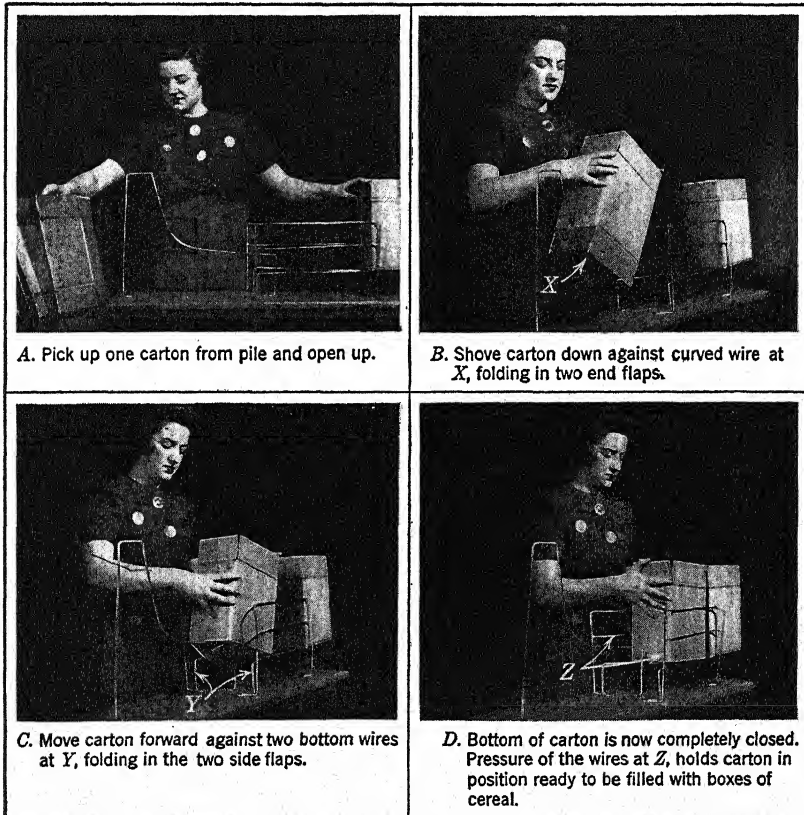


Fig. 192. Opening shipping cartons—improved method. Output was increased 112 per cent. Also as a result of this study the carton was redesigned, saving over \$20,000 per year in carton cost.

using the original method. The actual increase in output was 112 per cent. The fixture saves many hand motions in opening cartons. Also, as a result of this study, the carton was redesigned, saving over \$20,000 per year in carton cost.

**Refrigerator Door-Knob Assembly.** The assembly shown in Fig. 193 is a knob for a refrigerator compartment door. The parts consist of a plastic molded knob, A, a stamped aluminum bracket, B, contain-



ing a rubber bumper, *C*, a No. 8-32 machine screw, *D*, and a lock washer, *E*.

The rubber bumper was attached to one end of the bracket and a hole was drilled in the other end for the machine screw. The hole in the molded knob was threaded to receive the screw. Figure 193 shows the parts in position for assembly.

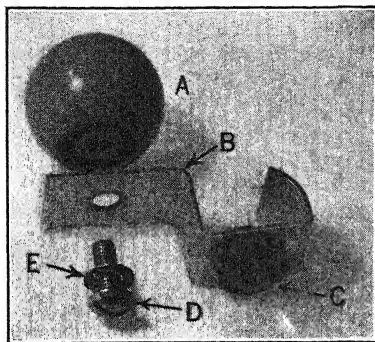


FIG. 193. Refrigerator door-knob assembly. A. Plastic molded knob; B. Aluminum bracket; C. Rubber bumper; D. Machine screw; E. Lock washer.

**Old Method.** The work place was arranged with the screws and washers dumped in piles on top of the table at the left of the operator. The plastic knobs were placed in a carton in front of the operator, the brackets were placed in a tote box at the right of the operator, and the finished assemblies were placed on the table beyond the box of brackets. Figure 194 shows the arrangement of the work place for the old method of assembly.

The procedure for assembling the parts was as follows. A number of screw and washer assemblies were made and placed on the table in front of the operator. A knob was then picked up with the left hand and held while the right hand picked up a bracket and placed it in position over the knob; the left hand held the knob and bracket while

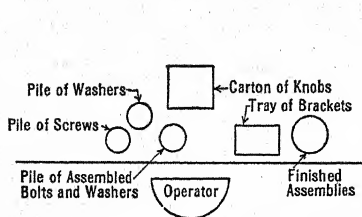


FIG. 194. Layout of work place for refrigerator door-knob assembly—old method.

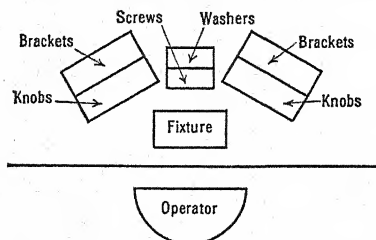


FIG. 195. Layout of work place for refrigerator door-knob assembly—improved method.

the right hand picked up a screw and washer and placed the screw through the hole in the bracket and into the tapped hole in the knob. The right hand then turned the screw down a few turns with a screw-driver, which was held in the palm of the right hand during the whole



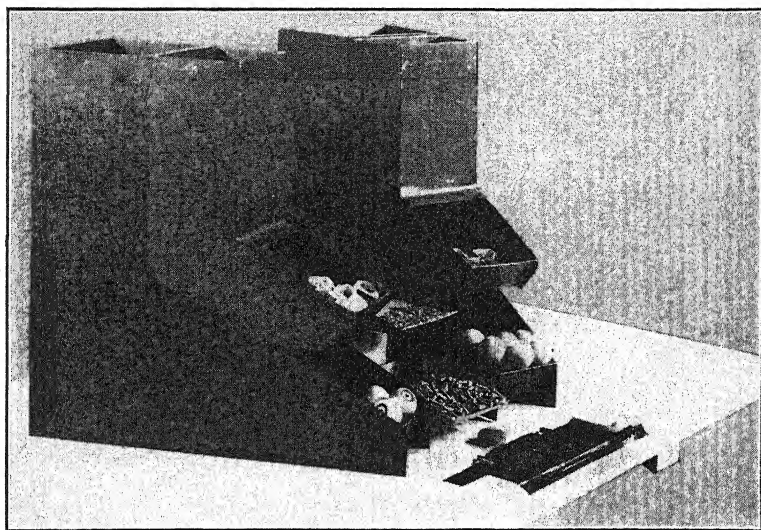


FIG. 196. Bins and fixture for assembling special door knobs—improved method. The standard bins are shown on either side of the fixture. The two small bins in the center have a lip on the front edge to facilitate grasping nuts and washers.

operation. The finished assembly was placed on the table to the right of the operator by the right hand.

**Improved Method.** The work place was rearranged with bins for the parts conveniently located as shown in Figs. 195 and 196. A special holding fixture operated by two foot pedals was placed in the table top and directly in front of the operator. Two stacked bins were placed on either side of the center bins. The top bin on each side contained the brackets, and the bottom bins contained the knobs. The finished assemblies were dropped down out of the fixture into a tote box under the table by means of a foot pedal which tilted the whole fixture downward.

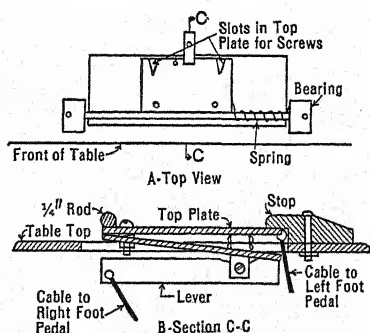


FIG. 197. Fixture used for refrigerator door-knob assembly. A. Top view; B. Cross section through center of fixture.

The jig consisted of two steel plates approximately 3 inches by 5 inches in size, as Fig. 197 shows. The top plate had two tapered



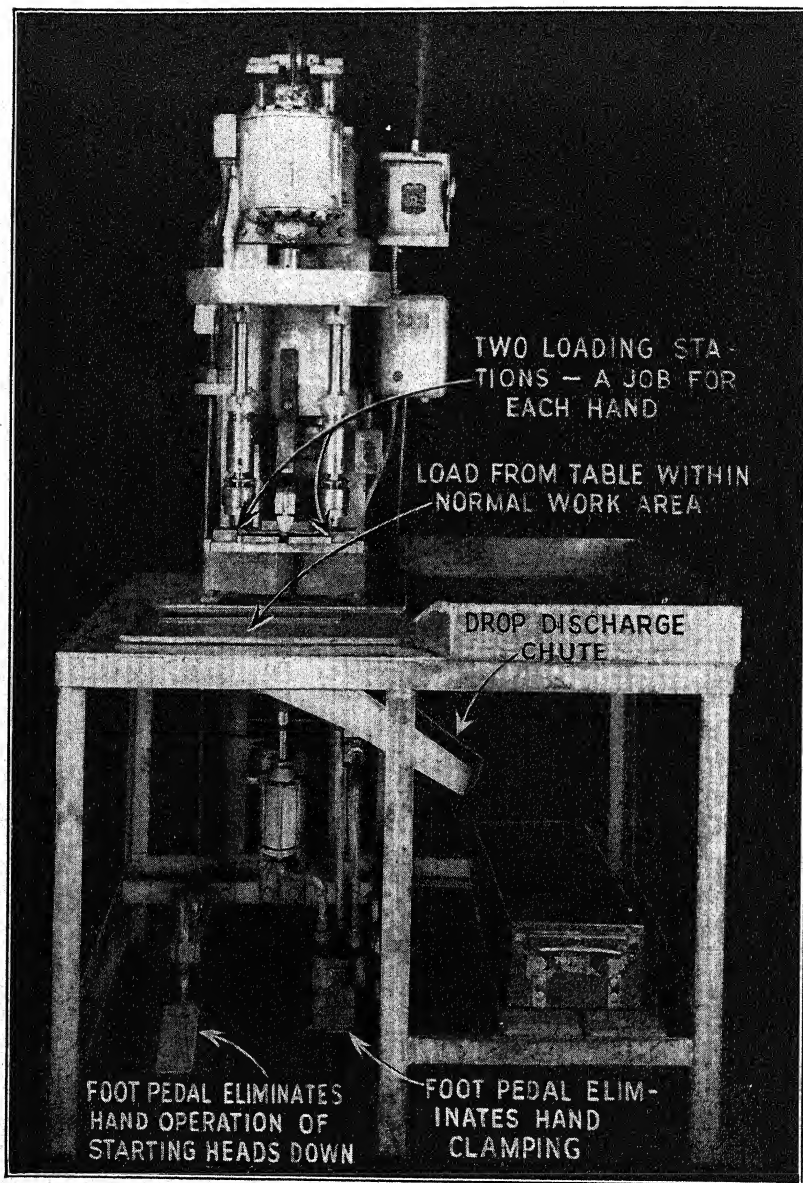
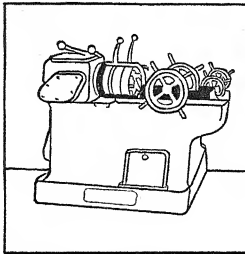


FIG. 198. Machine for rethreading ball studs—production rate 1100 per hour.

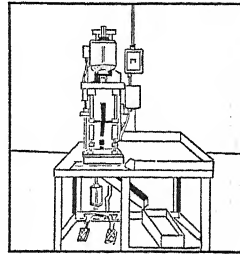


slots or notches in the edge away from the operator into which the screws were placed head down. The bottom plate was clamped against the heads of the screws by a lever mechanism actuated by a foot

PRODUCTION WAS INCREASED  
COST WAS REDUCED



OLD MACHINE



NEW MACHINE

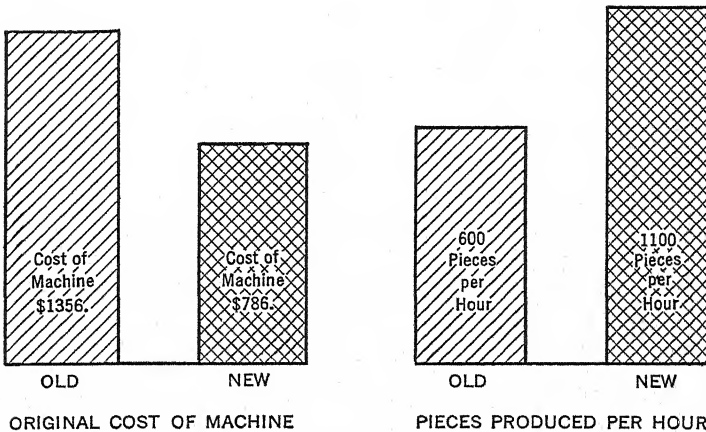


FIG. 199. Chart showing comparison of original cost and hourly production capacity of a standard rethreading machine and a new machine employing the principles of motion economy in its design.

pedal. A  $\frac{1}{4}$ -inch rod was welded to the back edge (nearest the operator) of the top plate and was supported at each end by bearings screwed fast to the table top. Another foot pedal connected by a cable to the front edge of the top plate served to tip the jig downward, thus dumping the finished assemblies into a chute. A coil spring on the  $\frac{1}{4}$ -inch rod returned the jig to the horizontal position after dumping the assemblies.



The assembly cycle for the improved method was as follows. A screw was picked up in each hand, placed head down in the slots of the jig, and clamped in place by depressing the right foot pedal. A washer was picked up in each hand and placed over the screws; likewise a bracket was placed over the screws, and a knob was picked up in each hand and placed over the screws and turned down two turns. The right foot pedal was released, releasing the assemblies from the clamping action of the fixture, and then the left foot pedal was depressed, dropping the two assemblies into the chute under the table. The two hands then reached for screws to begin the next cycle.

The improved method described above and worked out by James A. Hardy resulted in an increase in output of 143 per cent.

**Rethreading Machine.** The rethreading machine shown in Fig. 198, built at a cost of \$786, produces 1100 parts per hour.<sup>2</sup> It replaced a standard two-spindle threading machine which cost \$1356 and produced 600 parts per hour. (See Fig. 199.)

The improved machine, incorporating a number of principles of motion economy, was built under the direction of O. W. Habel, Factory Manager of Saginaw Steering Gear Division, General Motors Corporation.

Some of the reasons why the new machine enabled the operator to double his output are given here:

1. Hand motions were replaced by foot and mechanical movements. The operator, seated at the machine, picks up a blank with each hand, from a convenient position on the table, and places them in the two-station fixture. Pressure of the right foot on the air valve operates the clamping fixture. Pressure on the left foot pedal brings the die head down.
2. Work does not pass from one hand to the other, and the finished work is dropped down a chute into a tote box.
3. Hand and eye motions are kept within the normal working space.
4. The hands are not used for holding or for manipulating any machine parts. There are no small controls to hunt for and manipulate.
5. Clamping fixtures are provided with bell mouths to facilitate the positioning of the blanks.

It is scarcely necessary to cite further illustrations of foot-operated apparatus, for their use is so common. In fact the question might

<sup>2</sup>O. W. Habel and G. G. Kearful, "Machine Design and Motion Economy," *Mechanical Engineering*, Vol. 61, No. 12, p. 897, December, 1939.



properly be asked about almost any kind of bench or machine work, "Can a foot-operated device of some kind be used to facilitate the work?"

**Design of Foot Pedals.** Although the foot pedal is one of the most common devices for freeing the hands for productive work, most pedals are poorly designed.

Pedals might be classified as (1) those requiring considerable effort for manipulation and (2) those requiring little effort. The first-named class is well illustrated by the garment press and by certain foot-operated punch presses and shears. The second class is illustrated by the trip on the power punch press, the control on the electric sewing machine, and the pedals shown on pages 280-283.

Particularly in the first class, where considerable force is required for manipulation, the pedal should be of sufficient width to permit its operation by either foot. Some pedals are placed across the entire front of the machine in order to facilitate this. The pedal should also be designed so that the operating foot can carry part of the body weight. Poorly arranged pedals, such as the one shown in Fig. 200, tend to put all the body weight on one foot, throwing the body out of its normal position and resulting in excessive strain and fatigue for the operator.<sup>3</sup>



FIG. 200. Poorly designed pedal.

Where the operator is seated and where little effort is required to manipulate the pedal there should be a "steady rest" or a suitable support for one side of the foot or for the heel. The foot throttle or accelerator on the automobile is a good illustration of this. The accelerator pedals on most cars are well designed. The pedals shown in Figs. 188 and 200 are poorly designed; those in Figs. 187 and 189 are quite satisfactory.

It is sometimes desirable to have a cushioning device incorporated into the design of the pedal in order to check the swing gradually and prevent a sudden stop at the end of the swing. The pedal on some sheet metal shears and foot presses strikes the floor when it is depressed to its full extent, causing a sudden jar or shock which is transmitted

<sup>3</sup> L. A. Legros and H. C. Weston, "On the Design of Machinery in Relation to the Operator," Industrial Fatigue Research Board, *Report* 36, p. 13, 1926. Figure 200 reproduced by permission of the Controller, H. M. Stationery Office, London.



to the operator. A rubber or felt pad, a spring, or a dash pot might be used to prevent the sudden stopping of the pedal stroke. (See soft rubber pedal stop *E* in Fig. 186.)

**Study of Five Types of Pedals.** Figure 201 shows the results of a study<sup>4</sup> made to determine the relative effectiveness of five different types of pedals. Each pedal was depressed against a tension spring requiring 20 inch-pounds for one complete stroke. For example, pedal 1 had the fulcrum under the heel, and the ball of the foot moved through a distance of 2 inches against a resistance of 10 pounds. All

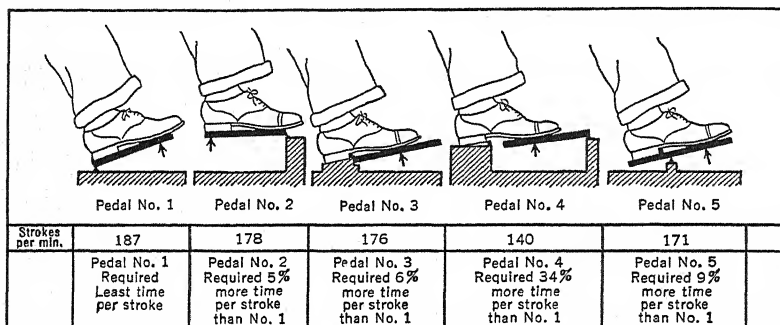


Fig. 201. Results of a study of five types of pedals.

the pedals were operated as trip type, such as would be found on a punch press. That is, the operator was asked to depress the pedal as rapidly as possible, and the time for each pedal stroke was measured with a kymograph. The results of the study (see Fig. 201) show that the operator using pedal 1 took the least time per stroke. Pedal 4 required the longest time—34 per cent more than pedal 1.

**Hand Tools Permanently Positioned for Using.** It is frequently possible to mount hand tools such as power-driven wrenches, screwdrivers, and electric soldering irons on fixed brackets in a suitable position for using.

For example, two small copper parts were soldered together in the following manner. An ordinary vertical liquid-soap dispenser with an outlet valve in the bottom was mounted rigidly above the bench and in front of the operator. Beside it was also mounted an electric soldering iron. Liquid flux, placed in the soap dispenser, was applied

<sup>4</sup> Ralph M. Barnes, Henry Hardaway, and Odif Podolsky, "Which Pedal Is Best?", *Factory Management and Maintenance*, Vol. 100, No. 1, p. 98, January, 1942.



to the copper parts by merely touching the parts up against the valve. The copper parts were then moved a short distance and brought up against the tip of the soldering iron. Solder from the tip of the iron flowed in between the two parts completing the operation. The operator supplied solder to the iron from a coil of wire solder which she carried in the palm of her hand.

In another case, that of assembling set screws in a small collar, an electric motor-driven wrench was mounted under the work bench. The chuck of the wrench projected up through a hole in the bench. The set screw was assembled into the collar by using one hand to place the screw in the wrench chuck while the other hand brought the collar into position for receiving the screw.

**18. TWO OR MORE TOOLS SHOULD BE COMBINED WHEREVER POSSIBLE.**

It is usually quicker to turn a small "two-ended" tool end for end than it is to lay one tool down and pick up another. There are many examples of the two-tool combinations—tack hammer and tack puller, two-ended wrench, pencil and eraser—and the designer of the



FIG. 202. Combination screwdriver and tweezers.

"hand-set" telephone used this idea when he incorporated the transmitter and the receiver in one unit.

Two very convenient tools which have been developed at a mid-western electrical-equipment company are illustrated in Figs. 202 and

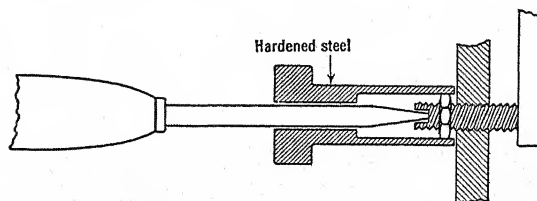


FIG. 203. Combination screwdriver and wrench.

203. The first one replaces the screwdriver and tweezers—it holds the screw while it is being assembled. The second tool replaces a wrench and a screwdriver. This device permits the bolt to be set to the proper position and at the same time allows the operator to lock



the nut in place by means of the "sleeve wrench" which slips over the screwdriver.

The attachments for spiral screwdrivers shown in Fig. 215 are also combination tools.

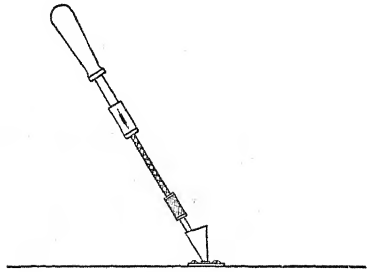


FIG. 204

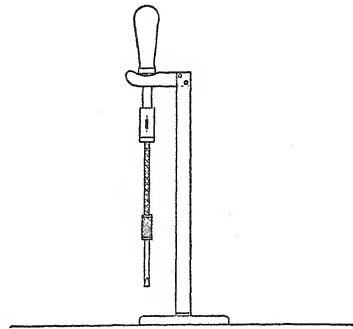


FIG. 205

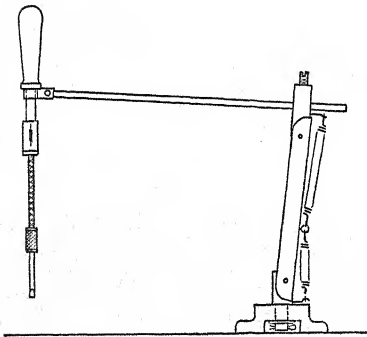


FIG. 206

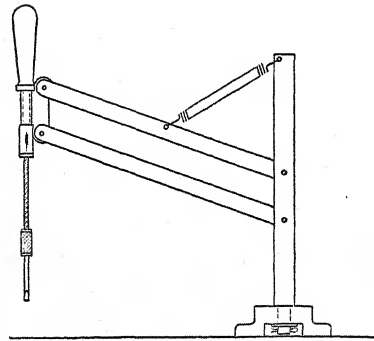


FIG. 207

Devices for pre-positioning spiral screwdrivers.

The practice of using only the thumb, first, and second fingers is so common that attention is called to the fact that the third and fourth fingers and the palm should also be used wherever possible. The combination screwdriver and wrench shown in Fig. 203, for example, permits the entire hand to be used. The thumb, first, and second fingers manipulate the wrench while the palm, third, and fourth fingers manipulate the screwdriver.

Small tools should be kept in the hand during the operation provided they do not interfere with the motions of the hand. It is frequently possible for the operator to hold a small tool in the hand constantly



and still be able to use the thumb, first, and second fingers without any loss in efficiency. In the operation of folding and creasing paper the operator held the bone in her hand continuously. See page 220.

**19. TOOLS AND MATERIALS SHOULD BE PRE-POSITIONED WHENEVER POSSIBLE.**

Pre-positioning refers to placing an object in a predetermined place in such a way that when next needed it may be grasped in the position in which it will be used. For pre-positioning tools, a holder in the form of a socket, compartment, bracket, or hanger should be provided into which or by which the tool may be returned after it is used, and where it remains in position for the next operation. The tool is always returned to the same place. The holder should be of such design that the tool may be quickly released into its place from the hand. Moreover, the holder should permit the tool to be grasped in the same manner in which it will be held while being used. The most familiar example of pre-positioning is the fountain-pen desk set where the pen is held in writing position even when not in use, and from or to which it may be easily and quickly removed or returned.

There are innumerable devices which aid in pre-positioning tools and materials, and only a few typical examples can be shown here. Since the spiral screwdriver is one of the most common small tools for assembly work, some devices for pre-positioning it will be described.

Figure 204 shows a funnel-shaped holder set at an angle with the bench top. The holder illustrated in Fig. 205 permits the screwdriver to be dropped into place between two curved prongs. The screwdriver in Fig. 206 is clamped to the end of the swinging arm of the holder. The spring at the back of the vertical member automatically draws the screwdriver up and back out of the way after it has been released by the operator.

The holder in Fig. 207, a form of a pantograph, was developed in Professor Porter's laboratory at New York University. The arm swings horizontally about the vertical axis and because of the panto-

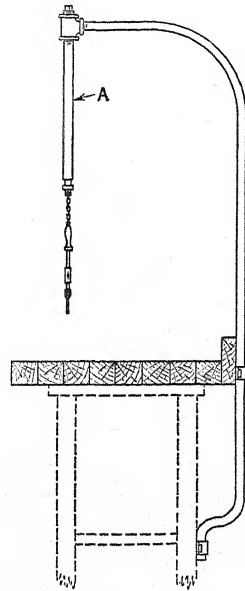


FIG. 208. Device for pre-positioning spiral screwdrivers.



graph action reduces the time required for positioning the screwdriver on screws or nuts to be assembled onto parts held in a jig.

The screwdriver in Fig. 208 is suspended from above the work place. A coil spring inside the vertical arm *A* pulls the screwdriver up out of the way when it is released.

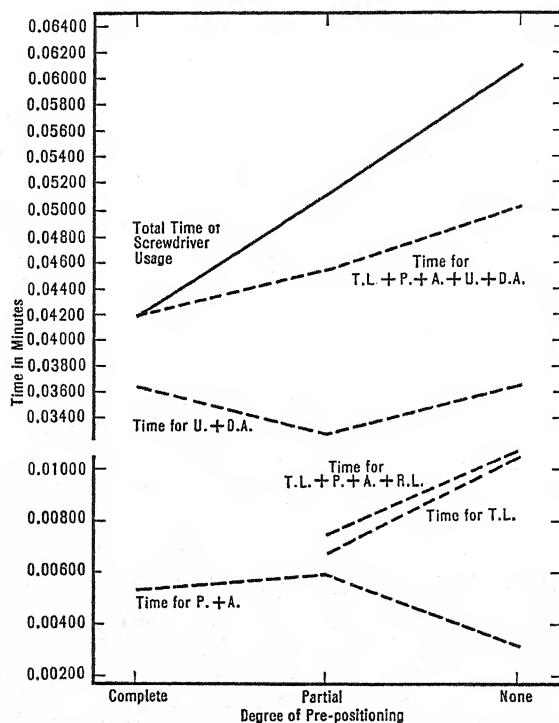


Fig. 209. Curves showing results of a study of screwdriver work with varying degrees of pre-positioning of the screwdriver. Averages of median time values for five male operators are shown.

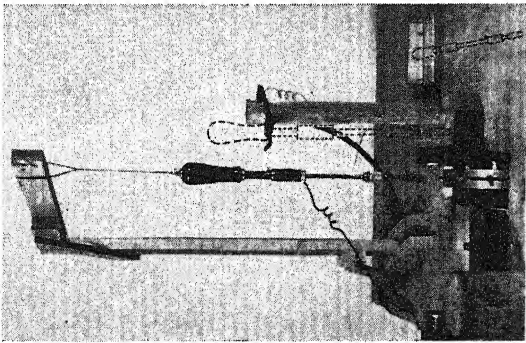
**Screwdriver Work with Varying Degrees of Pre-positioning.** The results of a study<sup>5</sup> of the time required to use a spiral screwdriver when completely pre-positioned, partially pre-positioned, and when lying flat on the bench are shown in Fig. 209 and Table XIX.

The operation consisted of grasping the screwdriver, carrying it to a screw which had already been started, positioning the screwdriver on the screw, and driving the screw down one-half inch until tight. The

<sup>5</sup> University of Iowa Studies in Engineering, *Bulletin* 16, p. 60.



TABLE XIX  
SCREWDRIVER WORK WITH VARYING DEGREES OF PRE-POSITIONING

	SCREWDRIVER USAGE				
	Time to grasp screwdriver, carry it to screw, position and assemble bit, run down No. 8 machine screw one-half inch in nut, remove screwdriver, and dispose.	Time in Minutes			
			Screwdriver Completely Pre-positioned	Screwdriver Partially Pre-positioned	Screwdriver Not Pre-positioned At All
			0.0417	0.0511	0.0610
			100	123	146
			Time in Per Cent (Shortest Time = 100%)		



screwdriver was then disposed of, and the wheel containing the screws was indexed to bring up the next screw into position for assembly.

The total time of *screwdriver usage* (the time from the instant the hand grasped the screwdriver until the instant it released it after running down a screw) was a minimum when the completely pre-positioned screwdriver was used. The partially pre-positioned screwdriver required on the average 23 per cent more time, and the screwdriver

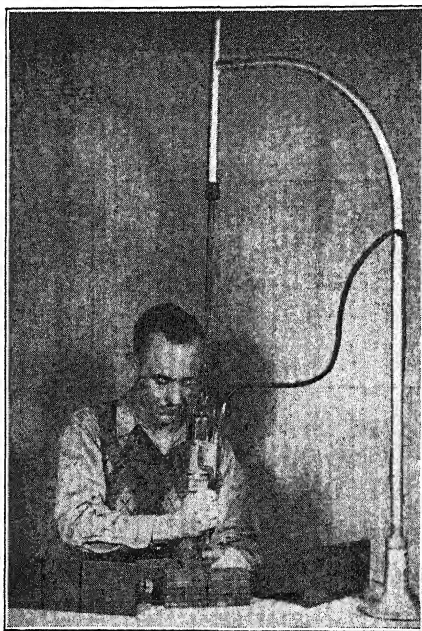


FIG. 210. Electric motor-driven wrench.

when not pre-positioned at all required 46 per cent more time for this part of the total cycle.

The special trays shown on page 250 may be used to advantage with screwdrivers mounted as illustrated in Figs. 206, 207, and 208. Special screwdriver attachments such as those shown on Fig. 215 would be required. The funnel-shaped guide in front of the chuck in Fig. 181 on page 273 assists in positioning hard-rubber parts.

**20. WHERE EACH FINGER PERFORMS SOME SPECIFIC MOVEMENT, SUCH AS IN TYPEWRITING, THE LOAD SHOULD BE DISTRIBUTED IN ACCORDANCE WITH THE INHERENT CAPACITIES OF THE FINGERS.**

The normal right-handed person performs work with less fatigue and greater dexterity with the right hand than with the left. Although



most people can be trained to work equally well with either hand on most factory operations, the fingers have unequal inherent capacities for doing work. The first and second fingers of the two hands are ordinarily superior in their performance to the third and fourth fingers.

A study made to determine the ideal arrangement of the keys of the typewriter for maximum efficiency also illustrates this difference

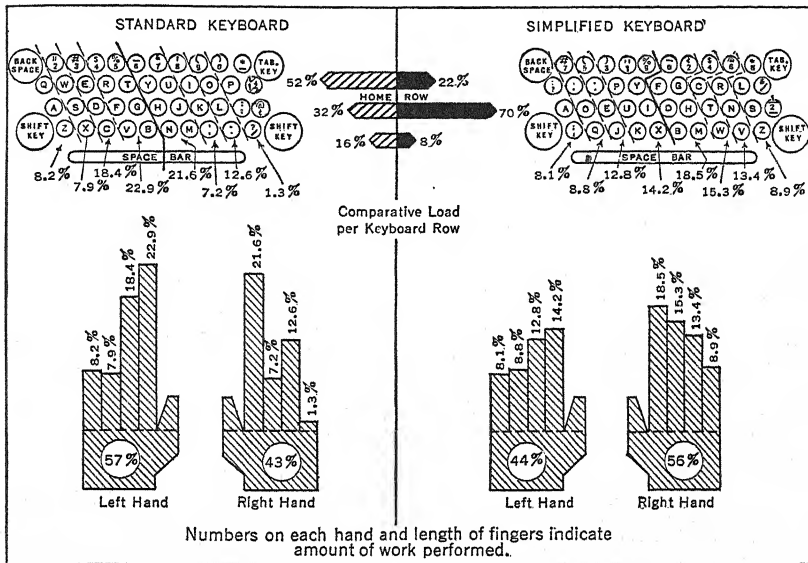


FIG. 211. Comparison of present typewriter keyboard with the new simplified keyboard. Figures indicate comparative loads for each row, hand, and finger. The new keyboard at the right has the letters rearranged so that the right hand carries its share of the load. Seventy per cent of the commonly used words are written on the "home row" where the fingers are placed.

in the capacities of the fingers.<sup>o</sup> First, an analysis was made of the frequency of occurrence of the twenty-six letters of the alphabet in several lists of the most commonly used words of the English language. Then a large number of typical business letters were analyzed to determine the frequency of occurrence of punctuation marks, capital letters, and other characters. Studies were conducted to determine the abilities of the eight fingers of the two hands for typewriting. This was done by means of tapping tests made for each finger, both on a typewriter and on a desk. With all this information, together with

<sup>6</sup> R. E. Hoke, "Improvement of Speed and Accuracy in Typewriting," *John Hopkins Studies in Education*, No. 7, pp. 1-42, 1922.



data on the errors made by the different fingers, it was possible to determine the ideal arrangement of the keys of the typewriter. (See Fig. 211.)

That part of the study which is of most interest here revealed that the ability of the right hand as compared to that of the left was as 100 to 88.87, or approximately as 10 to 9. This agrees with the findings of another investigator already cited.<sup>7</sup> The data in Table XX show the ideal load, in strokes, based on the abilities of the fingers.

TABLE XX

RELATIVE FINGER LOADS ON THE "IDEAL" AND ON THE PRESENT KEYBOARD

Finger	Left Hand				Right Hand			
	4	3	2	1	1	2	3	4
Ideal load	855	900	975	1028	1097	1096	991	968
Present keyboard load	803	658	1492	1535	1490	640	996	296

The finger loads required by the present typewriter keyboard are shown for comparison.

These data show that the first and second fingers of the right hand should carry the greatest load, whereas the fourth finger of the left hand should carry the smallest load. They also show that the total load of the right hand using the present typewriter is 3422, and of the left hand 4488, or a ratio of 100 to 131.25 when it should have been as 100 to 88.87. Thus there is an overload of the left hand of 47.7 per cent as compared with the load of the right hand.

It was suggested from the analysis of the data secured in this investigation that the keys of the typewriter should be so arranged that the letters occurring most frequently should be typed with the fingers capable of carrying the greatest load. In fact, many investigators in this field have proposed new keyboards. The one shown on the right in Fig. 211 is the Dvorak-Dealey "simplified" keyboard<sup>8</sup> tested over a

<sup>7</sup> Wm. L. Bryant, "On the Development of Voluntary Motor Ability," *American Journal of Psychology*, Vol. 5, No. 2, p. 123, November, 1892.

<sup>8</sup> A. Dvorak, N. I. Merrick, W. L. Dealey, and G. C. Ford, "Typewriting Behavior," p. 219. Copyright, 1936, by American Book Co., New York, and used by their permission.



period of years at the University of Washington as well as by some business concerns and by the U. S. Navy during the war. Researches conducted under a grant from the Carnegie Foundation for the Advancement of Teaching seem to indicate that the simplified typewriter keyboard eliminates many of the defects of the standard keyboard and that it is:

1. Easier to master in that it requires less time to attain any particular level of typing speed.
2. Faster, since it makes higher net rates possible for average typists.
3. More accurate, since fewer typing errors are made.
4. Less fatiguing through simplifying the stroking patterns and through adapting the hand and finger loads to the relative hand and finger abilities.<sup>9</sup>

**21. HANDLES SUCH AS THOSE USED ON CRANKS AND LARGE SCREWDRIVERS SHOULD BE DESIGNED TO PERMIT AS MUCH OF THE SURFACE OF THE HAND TO COME IN CONTACT WITH THE HANDLE AS POSSIBLE. THIS IS PARTICULARLY TRUE WHEN CONSIDERABLE FORCE IS EXERTED IN USING THE HANDLE. FOR LIGHT ASSEMBLY WORK THE SCREWDRIVER HANDLE SHOULD BE SO SHAPED THAT IT IS SMALLER AT THE BOTTOM THAN AT THE TOP.**

Two studies have been made which furnish results that have a bearing on the shape and size of handles that are most effective. One study gives results on four different shapes of handles used in turning a crank. The subject grasped the handle and turned the crank at a uniform speed against a brake, the load being applied in known amounts. The grip of the operator's hand was measured before and after turning the crank. It was assumed that the least effective handle caused greatest decrease in the pressure that the operator could exert in gripping the hand dynamometer. The most effective handle by this test was one with the main part straight (handle C in Fig. 212), except that

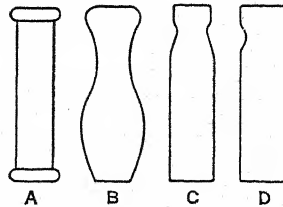


FIG. 212. Types of crank handles tested.

<sup>9</sup>Dwight D. W. Davis, "An Evaluation of the Simplified Typewriter Keyboard," *The Journal of Business Education*, Vol. 11, No. 2, p. 21, October, 1935. A. Dvorak, "There Is a Better Typewriter Keyboard," *National Business Education Quarterly*, Vol. 12, No. 2, pp. 51-58, December, 1943.



there was a slight indentation near the tip of the forefinger. Handles *B* and *D* in Fig. 212 were the poorest of the four.<sup>10</sup>

Another study was made to determine the most effective large screwdriver handle. A number of different types of screwdriver

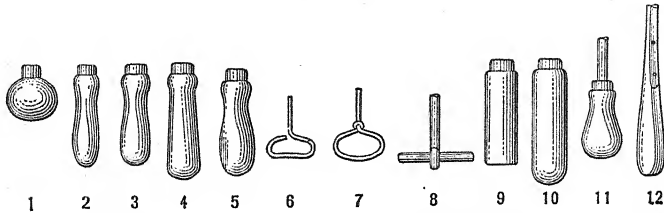


FIG. 213. Types of screwdriver handles tested.

handles were made in different diameters ranging from approximately  $\frac{3}{4}$  of an inch (18 mm.) to  $1\frac{1}{2}$  inches (40 mm.), and tests were made on each type, varying the diameter. Handle 10 (Fig. 213), which has a straight shank with a rounded end, was most efficient of all.

This handle had the same general shape as the most effective crank handle shown in Fig. 212. The relative efficiencies of the other handles are shown in Fig. 214.

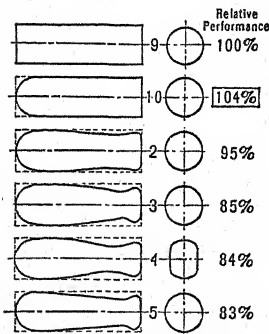


FIG. 214. Types of screwdriver handles that were most effective.

The object of the first test of the screwdriver handles was to determine the handle with which the operator could exert the maximum force in turning it through six-tenths of a revolution. Another set of tests was made in which the operator used the screwdriver to lift a weight by turning a screw for half a minute, and the amount of work done was computed. In both parts of this study, handle 10, Fig. 214, was most effective. The results also showed that

within the range tested, 18 mm. to 40 mm., the larger the diameter the more effective it was.<sup>11</sup>

<sup>10</sup> O. Klemm and F. Sander, "Experimentelle Untersuchungen über die Form des Handgriffes an Drehkurbeln" (Experimental Research on the Shape of Handles for Cranks), *Praktische Psychologie*, Vol. 4, pp. 300-302, 1923.

<sup>11</sup> B. Rubarth, "Untersuchung zur Bestgestaltung von Handheften für Schraubenzieher und ähnliche Werkzeuge" (Investigation Concerning the Best Shape for Handles for Screwdrivers and Similar Tools), *Industrielle Psychotechnik*, Vol. 5, No. 5, pp. 129-42, 1928.



All information on this subject seems to show that where the hand carries a load, as in carrying a pail, turning a crank or screwdriver, the maximum efficiency results when the unit pressure on the hand is lowest. This means that the largest surface of the hand possible should be used in grasping the handle. The two investigations described above did not cover the use of screwdrivers for light work, such as the assembly of small screws or nuts.

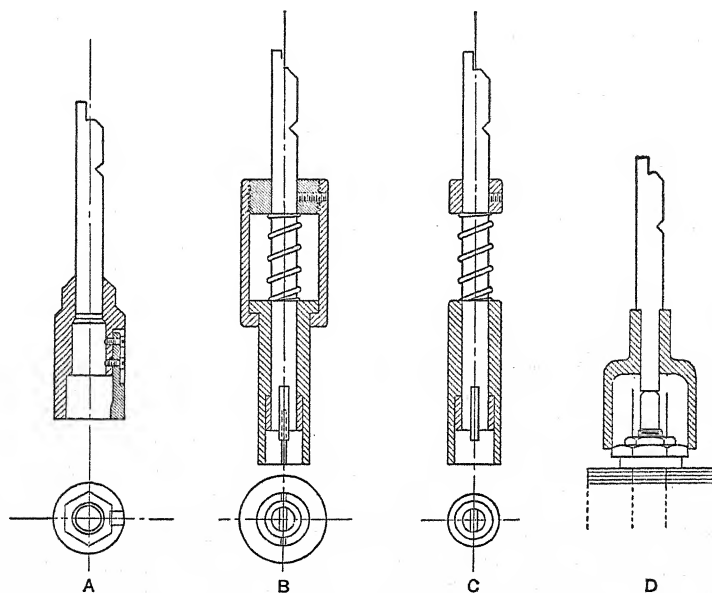


FIG. 215. Spiral screwdriver attachments. A. Wrench for picking up hexagon nut and positioning it for assembly. B. Screwdriver blade for picking up machine screw from special tray and positioning it for assembly. C. Self-centering screwdriver blade. D. Hexagon socket wrench for assembling nut on end of armature shaft. Wrench automatically slips off nut after it has been assembled a predetermined distance.

**Plain Screwdrivers for Light Work.** Most of the assembly work in the shop and factory requires the use of a light or medium-sized screwdriver rather than a large one. In many cases operators use screwdrivers that are too large for this light class of work. Tests show that the best plain screwdriver for such work is a short one, small in diameter near the blade and with a rotating finger rest on the top. The screwdriver handle should be large in diameter near the top and should be completely knurled from top to bottom. By pressing the index finger on the rotating top and gripping the thin



knurled part of the stem between the thumb and second finger the screwdriver may be rotated very rapidly for assembling the screw. By using the upper part of the handle with the large diameter the screw may be properly driven home.

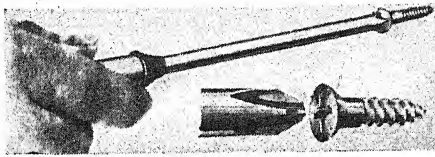


FIG. 216. Phillips recessed head self-centering screw, and screwdriver bit.

Tests<sup>12</sup> show that the use of such a screwdriver will result in an increase in output of 15 to 25 per cent over that produced with a larger one of the conventional type.

In preparing to use a screwdriver many people make the mistake of grasping it at the top, then by resting the blade against the bench they slide the hand down to the bottom of the handle. Instead, they should grasp the lower end of the screwdriver with the thumb and index finger and move it to the screw, the other hand helping to position it into the screw slot.

**Spiral Screwdrivers.** The spiral screwdriver is often superior to the plain screwdriver for light and medium work. It may be used for assembling nuts and bolts as well as for screws. Perhaps the best type is the "quick return" model with a spring in the handle, causing the handle to come back automatically for the next stroke.

There are many time-saving devices which may be used with the spiral screwdriver. A special wrench for picking up a hexagon nut is shown in Fig. 215A and a similar device for picking up a round-head machine screw is shown in Fig. 215B. Special trays for holding the nuts and machine screws are used in connection with these two attachments. One study showed that the time required to insert an ordinary screwdriver bit in the slot of a No. 8 machine screw with a round head was 194 per cent more than when a bit with a self-

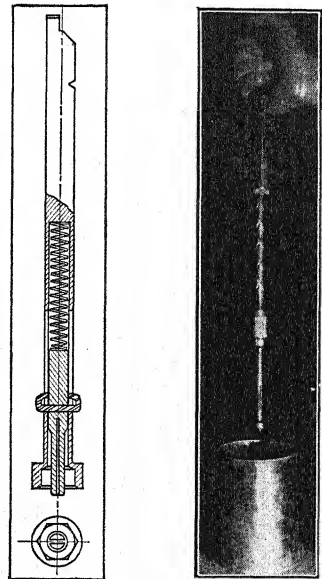


FIG. 217. Special screwdriver attachment for picking up hexagon nut and positioning it for assembly.

<sup>12</sup>L. I. Hunt, "A Study of Screwdrivers for Small Assembly Work," *The Human Factor*, Vol. 8, No. 2, pp. 70-73, February, 1934.



centering attachment, similar to that shown in Fig. 215C, was used. Such a bit may be used to advantage with such pre-positioning devices as those shown on page 294. Figure 215D shows a hexagon socket wrench for assembling a nut onto the end of an armature shaft. The wrench automatically slips off the top of the nut after it has been assembled onto the end of the shaft a predetermined distance.

The screwdriver bit shown in Fig. 217 is used by thrusting it into a container which is well filled with nuts. The split pilot projecting through the middle of the hexagon wrench picks up the nut by penetrating through the threaded hole in it. When the wrench with the nut is placed on the bolt, the pilot withdraws from the nut, and the nut is assembled onto the bolt by means of the hexagon wrench. This special tool was developed by the Colonial Radio Corporation, and many of these tools are in constant use by this company.

Figure 216 shows a Phillips recessed head self-centering screw and screwdriver bit.

**22. LEVERS, CROSSBARS, AND HAND WHEELS SHOULD BE LOCATED IN SUCH POSITIONS THAT THE OPERATOR CAN MANIPULATE THEM WITH THE LEAST CHANGE IN BODY POSITION AND WITH THE GREATEST MECHANICAL ADVANTAGE.**

Some machine-tool manufacturers understand that it is possible to build a machine that will perform its functions satisfactorily and at the same time will be easy to operate.

Unless a machine is fully automatic, the amount of work that it will produce depends to some extent upon the performance of the operator. The more convenient the machine is to operate, the greater the production is likely to be.

The Gisholt Machine Company, for example, has incorporated a speed selector in their new universal turret lathes. (See Fig. 218.) This device enables the operator to obtain easily and quickly any one of the several available spindle speeds. It is power-operated—the operator simply sets a dial, and the machine automatically makes the shift to give the correct spindle speed.

The operator standing or sitting in a normal working position should not be required to leave his place of work to operate his machine. The levers should be placed in such a way that he need not bend over or twist his body in an uncomfortable manner when manipulating them. Where this ideal condition cannot be provided the nearest approach to it should be adopted. (See Fig. 219.)

It is well known that levers can be operated more effectively in certain positions and at certain heights than at others. A very



exhaustive study was made to determine the effectiveness of levers, crossbars, and hand wheels located in both horizontal and vertical planes, and at three different heights from the floor.<sup>13</sup> These devices were arranged so that the force of the push or pull was indicated in kilograms by means of a dynamometer. It was the object in these tests to determine the maximum strength that could be exerted in

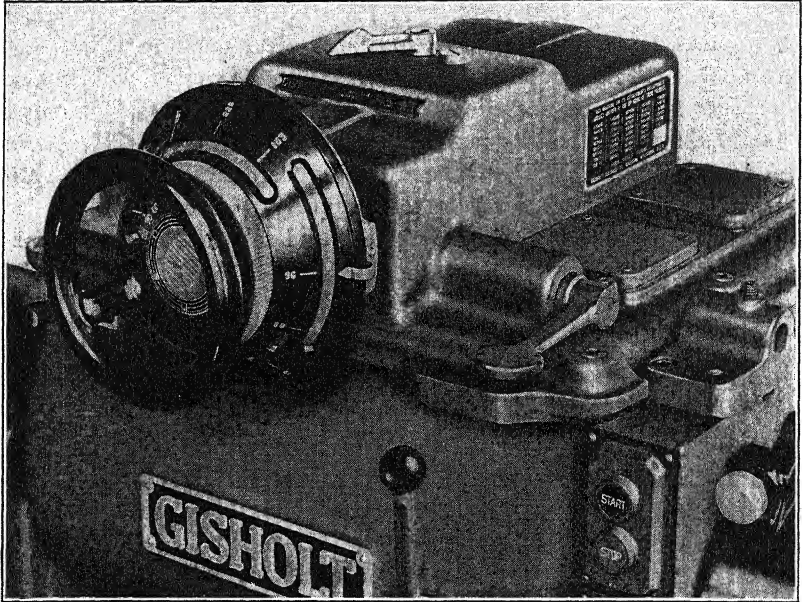


FIG. 218. Speed selector for universal turret lathe. This device simplifies the operation of changing spindle speeds—eliminates many motions and saves time.

each case. Each of the three devices was tested in the several positions shown in Figs. 220, 221, and 222.

The vertical scale represents the force in kilograms exerted by the subject, and the horizontal scale shows the particular position of the device being tested. The three sets of curves on each chart represent the three different heights at which the devices were tested, namely 580 mm. (22.8 inches), 780 mm. (30.7 inches), and 1080 mm. (42.5 inches). For example, in Fig. 220 the lever was most effective at the medium height, 780 mm. above the floor, and position II on

<sup>13</sup> W. P. Kühne, "Studien zur optimalen Kraftreaktion an Maschinenbedienungselementen" (Studies on the Optimum Force Exerted on Machine Controls), *Industrielle Psychotechnik*, Vol. 3, No. 6, pp. 167-172, June, 1926.







the horizontal scale which represents the position where the lever was horizontal and the operator pulled up on it.

The hand wheel was most effective when placed at the 1080-mm. height and in the vertical plane, position IV in Fig. 222. The operator, standing off to one side of the wheel, pushed with his right hand and pulled with his left.

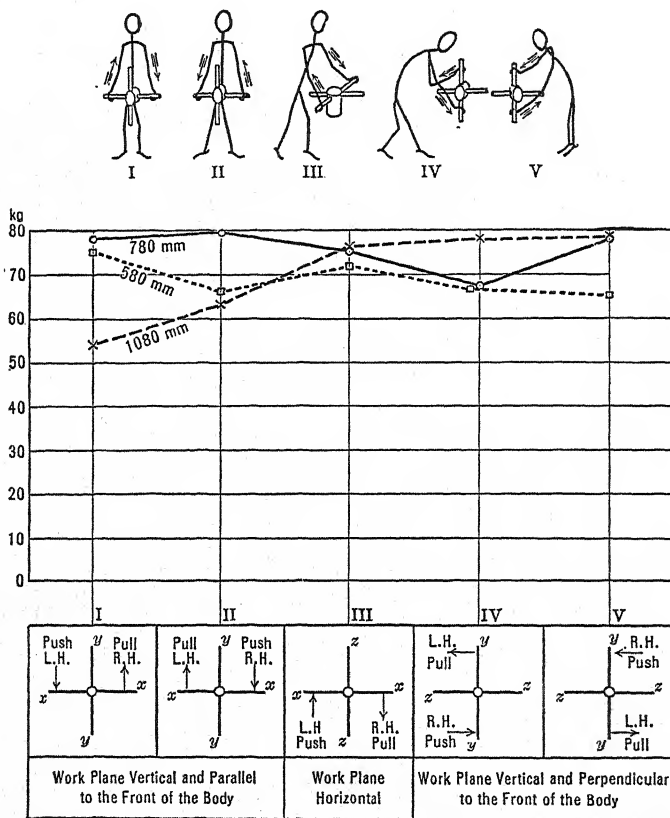


FIG. 221. Results of the study of crossbars.

**Maximum Pull and Height above Floor Level.** In a series of carefully conducted tests, Vernon determined the maximum strength which could be exerted in pulling at various heights above the floor level.<sup>14</sup> The pull was made in the vertical direction, and its extent

<sup>14</sup> E. M. Bedale and H. M. Vernon, "The Effect of Posture and Rest in Muscular Work," Industrial Fatigue Research Board, *Report* 29, p. 32, 1924. Figure 223 reproduced by permission of the Controller of H. M. Stationery Office, London.



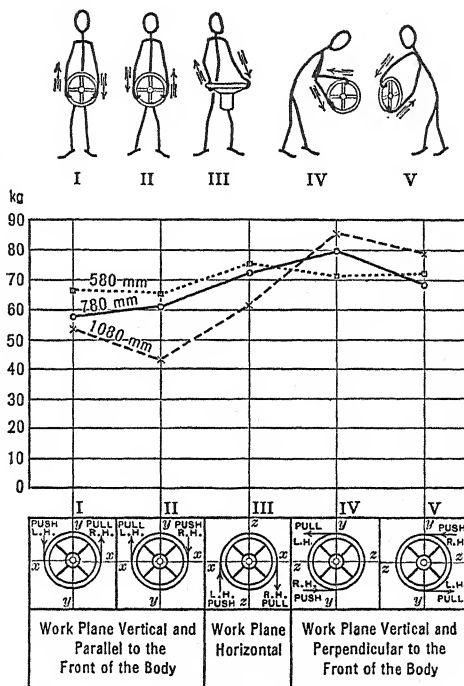


FIG. 222. Results of the study of hand wheels.

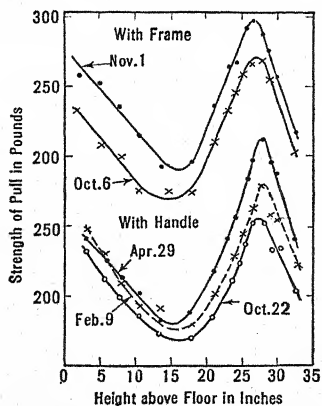


FIG. 223. Maximum pull at various heights above floor level.



was measured by a dynamometer. The curves in Fig. 223 show the results. The lower set of curves show trials made on three different days. In this test the subject grasped a handle with the two hands.

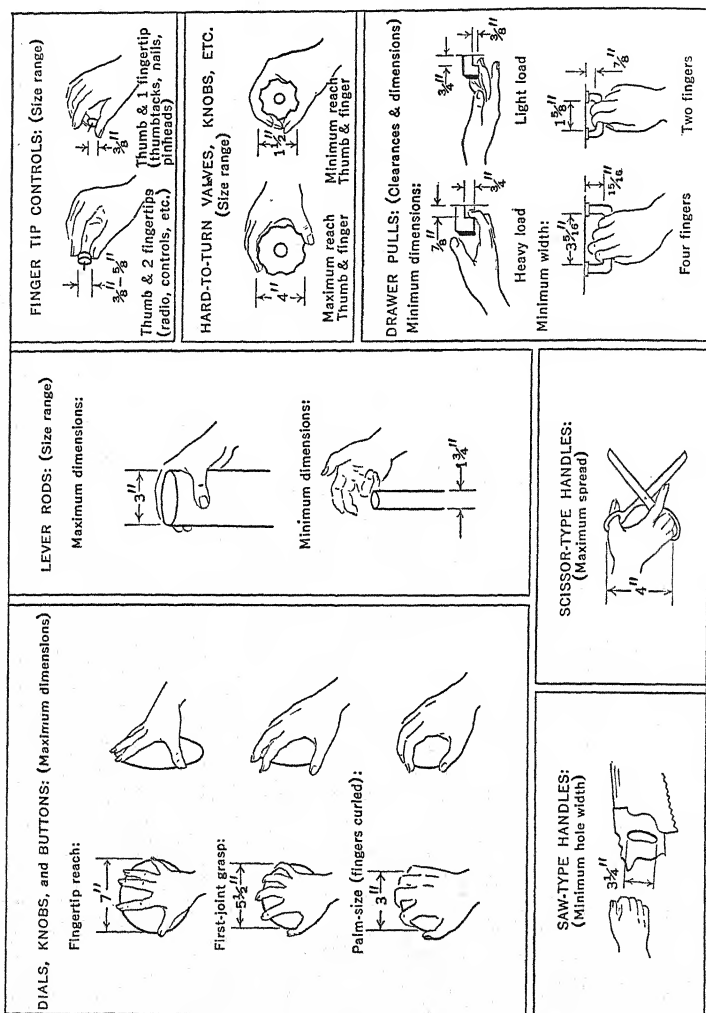


FIG. 224. Sketches showing how hand dimensions influence handle design, and control handle sizes.<sup>15</sup>

The handle, shaped much like a lawn-mower handle, was held close to the body and directly in front of the subject. The upper curves were plotted from results obtained by pulling vertically upward as before, but in this test the hands grasped the two sides of a rectangular

<sup>15</sup> Above sketches by Van Doren, Nowland and Schladermundt. Reprinted from *Modern Industry*, Vol. 14, No. 4, p. 51, Oct. 15, 1947.



frame made of iron pipe. The subject stood inside the frame and could grip the pipes which formed the ends of the rectangle. The hands, then, were in their normal position at either side of the body and not in front as in the test made using the handle. As the curves in Fig. 223 show, the frame made it possible for the subject to lift a greater load.

The results shown in the table below and by the curves might be summarized as follows. The strength of a pull or its equivalent, lifting a weight, varies considerably at different heights above the floor level. The strength is lowest when the height is 15 to 17 inches

RELATIVE STRENGTH OF PULL

Conditions	Subject I	Subject II
Standing on both feet and using both hands	100	100
Standing on right foot and using both hands	98	96
Standing on left foot and using both hands	98	98
Standing on both feet and using right hand	55	49
Standing on both feet and using left hand	52	54

above the floor and reaches a maximum at a height of 28 inches above the floor. The curves fall off rapidly at greater heights. The data in the table show that the lifting power falls off about 2 per cent when the subject is standing on one leg instead of two. However, the lifting power is but one-half as great when one hand is used instead of two.

**Cost Reduction Report.** It is essential that an estimate be made of the expected savings resulting from improvements in methods before they are made and also that a report be made after the project is finished and in effect.

The Cost Reduction Report shown in Fig. 225 is used for presenting proposed changes to the plant superintendent and also for reporting the savings from new methods after they are installed.

Unit operation times for the old and new methods are based on time studies or on overall production rates, whichever gives the most representative results for the particular project. Labor costs are based on the average base rate for the particular job plus the average bonus for the department and a percentage to cover compensation insurance, federal pension, old age insurance, and other costs that are directly related to labor cost.

Calculated savings do not include fixed overhead costs such as supervision and machine burden, since the annual expenditure for these



items would not necessarily be lessened by reducing the labor requirements of a particular job. If a proposed change would increase ma-

COST—REDUCTION REPORT			
<b>DESCRIPTION OF ITEM INVOLVED</b>		FILE 11-B	
DEPT. Finished Stock & Shipping		DEPT. NO. 64      DATE 12-12-47	
OPERATION Marking with name and address of consignee.		PRODUCT Cartons to be shipped	
OBJECT OF ANALYSIS To determine possible savings through stamping instead of stenciling.			
COMPARISON			
PRESENT METHOD		PROPOSED METHOD	
<b>MACHINE</b>		<b>MACHINE</b>	
TOOLS Fountain stencil brush and pre-cut stencil.		TOOLS Rubber stamp and stamp pad.	
DESCRIPTION Stencils are prepared in advance and kept on file for all major consignees, and name and address is stenciled on each carton.		DESCRIPTION Rubber stamps would be made up for all major consignees, and name and address is stamped on each carton.	
<b>COST OF OPERATIONS INVOLVED</b>	<b>\$ PER</b>	<b>COST OF OPERATIONS INVOLVED</b>	<b>\$ PER</b>
LABOR 0.16 minute per carton @ \$0.75 per man-hour	carton  0.0020	LABOR 0.05 minute per carton @ \$0.75 per man-hour	carton  0.0006
MATERIALS		MATERIALS	
MISC.		MISC.	
<b>TOTAL OF ABOVE ITEMS</b>	0.0020	<b>TOTAL OF ABOVE ITEMS</b>	0.0006
<b>ESTIMATE OF SAVING</b>			
SAVING WITH PROPOSED CHANGE (\$ 0.0020 — \$ 0.0006 ) EQUALS \$ 0.0014 PER carton			
PROBABLE YEARLY REQUIREMENTS, 1,250,000 cartons		ESTIMATED BY Sales Dept.	
ESTIMATED SAVINGS PER YEAR (BASED ON 1,250,000 PER YEAR)		\$ 1750.00	
<b>ESTIMATED COST OF CHANGE</b>		PROBABLE SAVINGS PER YEAR — \$ 1500.00	
DESIGN \$	EST. BY	LESS TOTAL COST OF CHANGE — \$ 300.00	
EQUIPMENT \$ 300.00	" "	NET SAVINGS FIRST YEAR — \$ 1200.00	
INSTALLATION \$	" "	NEW METHOD WOULD PAY FOR ITSELF IN 2½ MONTHS.	
\$	" "	NOTE: 60 rubber stamps required at \$5.00 each.	
\$	" "	SUGGESTED BY John Ryan	
<b>TOTAL COST OF CHANGE \$ 300.00</b>		REPORT PREPARED BY T. A. Wilson	
<b>CC TO</b>	<b>ATTACHED ARE</b>	<b>DATE</b>	<b>DATE</b>
	1 SHEETS DRAWINGS	FIRST CONSIDERED 12-2-47	EXPEN. APPR.
	SHEETS PRINTS	INVTGN. STARTED 12-4-47	INSTALLED
	2 SHEETS DETAILS	REPT. SUBMITTED 12-12-47	FINAL REPT.

8119

Fig. 225. Cost-reduction report. Size of form  $8\frac{1}{2} \times 11$  inches.

chine capacity, and if the additional capacity might forestall having to buy more equipment, this fact would be brought out in a note attached to the Cost Reduction Report.



## CHAPTER 18

### STANDARDIZATION

#### WRITTEN STANDARD PRACTICE

After finding the most economical way of performing an operation it is essential that a permanent record be made of it. This record is frequently called a "standard practice." In addition to serving as a permanent record of the operation, the standard practice is often used as an instruction sheet for the operator or to assist the foreman or instructor in training the operator.

**The Standard Practice as a Permanent Record.** Once the improved method is standardized and put into effect, constant vigilance on the part of management is necessary in order to maintain this standard. Often tools and equipment get out of adjustment, belts become loose, and materials vary from specifications. When such conditions exist, standard performance cannot be expected from the operator. Only by rigid maintenance of standard conditions can there be reasonable assurance of standard performance in output and quality.

Since most time standards are used as the basis for wage incentives and since most incentive plans either imply or specifically state that time standards, or rates, will not be changed<sup>1</sup> unless there is a change in the method of performing the work, it is essential that an accurate and complete record be made of the method at the time it is put into effect, or at the time the rate is set for the operation. If no such record is kept it will be almost impossible in the future to tell whether the method then being used is the same as that in effect at the time the standard was originally established.

One company uses the forms shown in Figs. 226 and 227 as a permanent record of each operation. This standard practice is ordinarily prepared by the person making the motion and time study or by the person in charge of the investigation if several men are engaged in the work. These two forms are prepared after the correct method has been

<sup>1</sup> "Industrial Engineering Survey," University of Iowa, *Industrial Engineering Report* 100, p. 3, 1946.



FIG. 226. Standard Job Conditions form, size  $8\frac{1}{2} \times 11$  inches.

FIG. 226. Standard Job Conditions form, size  $8\frac{1}{2} \times 11$  inches.







NOTE: Standard Collet Chuck with  $1\frac{1}{2}$  Hex. Bushings

PART NO. HB-443	NAME Hex. Bolt	MATERIAL SAE-X-1315	ASSUMED AVERAGE PER REV.	FEED PER REV.	SURFACE FEET PER MIN. CARBIDE H.S.S.	2.3 MIN. PER PC.	20.8 PCS. PER MIN.-HR.	48
CUSTOMER Preston Machine Co.			REFERENCE		ROUGH .012	200		
MACHINE No. 5-M-1740			SPEED 200% STD. 1750 RPM		FINISH .007		400	
ESTIMATE Sample			SET-UP 1		CHUCKING 1 OF 1		BY LDL Zath	
					DATE 2-25-47		CHK. H.R.G.	

PRODUCTION										MACHINE EQUIPMENT AND TOOLING PRICE DETAIL									
OPER. NO.	DIAM'S	FEET PER MIN.	FEED PER REV.	MIN. PER INCH	LENGTH OF CUT	TIME	TOOL NAME OR NUMBER	ST'D MACH. EQUIPMENT	STANDARD TOOLS	PURCHASED EQUIP'T	SPECIAL TOOLS	DURABLE	PERISH'LE	DURABLE	PERISH'LE				
1						.20	Revolving Stock Stop												
2	$1\frac{1}{2}$ "	215	.012	.15	$2\frac{3}{8}$ "	.35	Multiple Cutter Turner with 2 Carbide Cutters												
3	$\frac{3}{4}$ "	52	H/	—	$\frac{3}{8}$ "	.15	End Face & Form Tool with 1 High Speed Steel Cutter												
4	$1\frac{1}{2}$ "	215	.007	.25	$\frac{3}{4}$ "	.10	Special Block & 2 Carbide Cutters												
5	$\frac{3}{4}$ "	40	.198	16 P	$\frac{3}{4}$ "	.05	Die Head with High Speed Steel Chasers to Cut $\frac{3}{4}$ -16 Threads												
6	$1\frac{1}{2}$ "	75	.198	.0045	1.10	.85	High Speed Steel Cutoff Cutter												
UNLOAD																			
TOTALS						1.50	.80												
FLAT TIME MINUTES PER PIECE						2.30	SUB-TOTALS												
NOTE:						REMARKS:													
						(✓) CHECKED ITEMS PRICED ON PREVIOUS SET-UP.													

FIG. 228. Job setup and standard practice for operation on Warner and Swasey turret lathe. Size of sheet  $11 \times 16\frac{1}{2}$  inches.



established and put into effect. The "Standard Job Conditions" and the "General Job Conditions" forms used by this company are printed on bond paper, the first in yellow color and the second in salmon color. An original and one carbon copy of each of these forms are made out in pencil. The original is placed in the folder with the original time studies of the operation and filed in the Wage Standards Department office. The carbon copy is filed in a loose-leaf binder in the office of the foreman of the department in which the operation is performed. This is used by the operator, foreman, and time keeper.

The "Standard Job Conditions" form contains complete details of the specific operation; and the "General Job Conditions" form, as the name indicates, contains more general information about the operation and the location of the work place relative to the rest of the department or building, information about the flow of material to and from the work place, working conditions, and other similar matters.

Some classes of work are relatively simple, and written standard practices can be quickly prepared. On machine tool work, for example, the speed and feed, shape and size of tools, coolant used, and the method of chucking the piece are the important factors. The form in Fig. 291 on page 483, developed by one company primarily as instructions for the operator, also serves as the basis for their permanent record of the operation.

In some plants where many operations are similar, methods are frequently developed for a whole class of work, and time standards are determined from tables of standard data or formulas. In such cases similar operations can be grouped into classes for which one master standard practice can be prepared. For example (see Fig. 291), all sizes of gear blanks turned on Turret Lathe JL58 (Operation 5TR, Case D) follow the same sequence of motions of the operator and machine although the speeds, feeds, and the sizes of the tools vary with the size of the blank.

**Combination Computation Sheet, Instruction Sheet, and Written Standard Practice.** The Jones and Lamson Machine Company uses the form shown in Fig. 229 as a combination computation sheet, instruction sheet, and standard practice. The operation referred to is that of machining a sliding gear (see Fig. 230) on a No. 5 J & L universal turret lathe (see Fig. 231). This part is made in the Jones and Lamson plant. This is the way the time standard is determined and the way the instruction sheet (Fig. 229) is used.



That portion of the sheet which appears above the dotted line A-B is the part that goes to the operator. It shows him the standard set-

FULL SET UP	96.00	MIN.	1.60	HRS.	NAME 45T Sliding Gear			PART NO.	15073
PART SET UP		MIN.		HRS.	MACH. 5 MACH. SYMB. 412			OP. NO.	2
STD. PER PC.	7.10	MIN.	.118	HRS.	WRITTEN BY CBB APPR. BY WAS			DEPT. NO.	14
JOB CLASS			NE 8749	OPERATION DESCRIPTION			DATE		4/30/47

Drill, R & F turn  $3\frac{7}{8}$ " dia., R. bore 2.860" dia., face end and shoulder forming  $\frac{1}{8}$ " radius, chamfer hole and O.D. Hold on outside dia. with  $\frac{1}{2}$ " grip in hard jaws.

REAR

2/ R. turn  $3\frac{7}{8}$ " dia. 525 TO Internal to drill 82/

1 50 2 4 3

5/ F. face end and shoulder 480 TO, with  $\frac{1}{8}$ " radius. 481 TO 340/011

1/ Drill Adj. Mult. Turn. Head 2- $\frac{3}{8}$ " Drill 82/015

405 TO, 830 TO, 706 TO, 340/011

3/ R. bore 2.860" dia. Adj. boring slide 1- $\frac{3}{4}$ " Ang. Boring Bar 760 TO. 340/015

5 4/ F. turn  $3\frac{7}{8}$ " dia. & Chamf. hole & O.D. Adj. Mult. Turn. Head 1- $\frac{3}{4}$ " Ang. Cut Hldr. 1- $\frac{3}{4}$ " Str. Cut Hldr. 1- $\frac{3}{4}$ " Str. Bor. Bar.

1 HEX 4 2 3

NOTES: Leave  $\frac{1}{16}$ " stock in hole for finish later.

SET-UP	GENERAL SET-UP				SET-UP	BORE OR TURN JAWS			
	1ST OPER.	2ND OPER.	OP. SEQ.			AVERAGE 10.0	17.5	CLOSE LIMIT 17.0	21.0
	27.0	30.0	18.0	22.0	COMPLEX	TRUE UP 1ST PIECE IN 4 JAW CHUCK OR F. PLATE 5.00			
16.00	16.0	19.0	16.0	AVERAGE		P & R MULTIPLE TOOL BLOCK ON SQ. TURRET 4.00			
	12.0	12.0	12.0	SIMPLE		JIG ROOM 6.00			
	CHANGE CHUCK OR F. PLATE 17.00					P & R TOOL BLOCK ON REAR OF CROSS SLIDE 1.00			
10.00	CHANGE CHUCK JAWS 10.00					ADJUST MASTER LEADER & FOLLOWER 5.00			
	CHANGE COLLETS 6.00					SPINDLE STOP 9.00 6.00			
	P & R FIXTURE ON FACE PLATE				1.30	SET-UP GAGING			
1.30	SUB TOTAL 1				1.30	SUB TOTAL 1			
SET TOOLS	SET STOPS	POS. SEQ.	STD. MIN. PER IN.	TOOL TRAVEL	CUTTING STD.	C.S. HLDG.	HEX. HLDG.	GAG. INC.	P & R WORK
4.00	1.50	1	1.12	.71	2	2.95	.05		ADD 4 JAW CH.
7.00	3.00	2		Int.	Int.				CRANE 5.00
10.00	1.50	3	.27	2	.54		.10	.02	REL. STRAIN .25
26.00	1.50	4	.37	1- $\frac{3}{8}$	.51		.30	.06	RELIEVE DRILL
11.00	3.00	5	.37	$\frac{3}{4}$	.28	.70		.04	REM. CORE 25.50
									INDICATE .85
									CHGE. SPEED .10
									CLEAR CHIPS .25
									BURR .10/DIA.
									STAMP .10
									C.S. HANDLING .70
									HEX. HANDLING .45
									GAGING .12
									CUTTING STD. 4.50
									TOTAL 7.07
10.50	10.50	S.S.TOT.	TOTAL FACTOR		4.28	.70	.45	.12	NO. OF PIECES 1
95.80			CUTTING STD.		1.05				TOT. STD. MIN. 7.10
96.00	STD. MIN. SET-UP				4.50				PER. PIECE

Fig. 229. Combination computation sheet, instruction sheet, and written standard practice. Size of sheet  $8\frac{1}{2} \times 11$  inches.

up time and standard operation time per piece. This information appears at the top left of the sheet. For Operation 2 (first operation on the turret lathe) the operator is allowed 96 minutes or 1.6 hours to set up his machine, and 7.10 minutes or 0.118 hour to machine each piece. Next follows instructions for machining the piece. Underneath



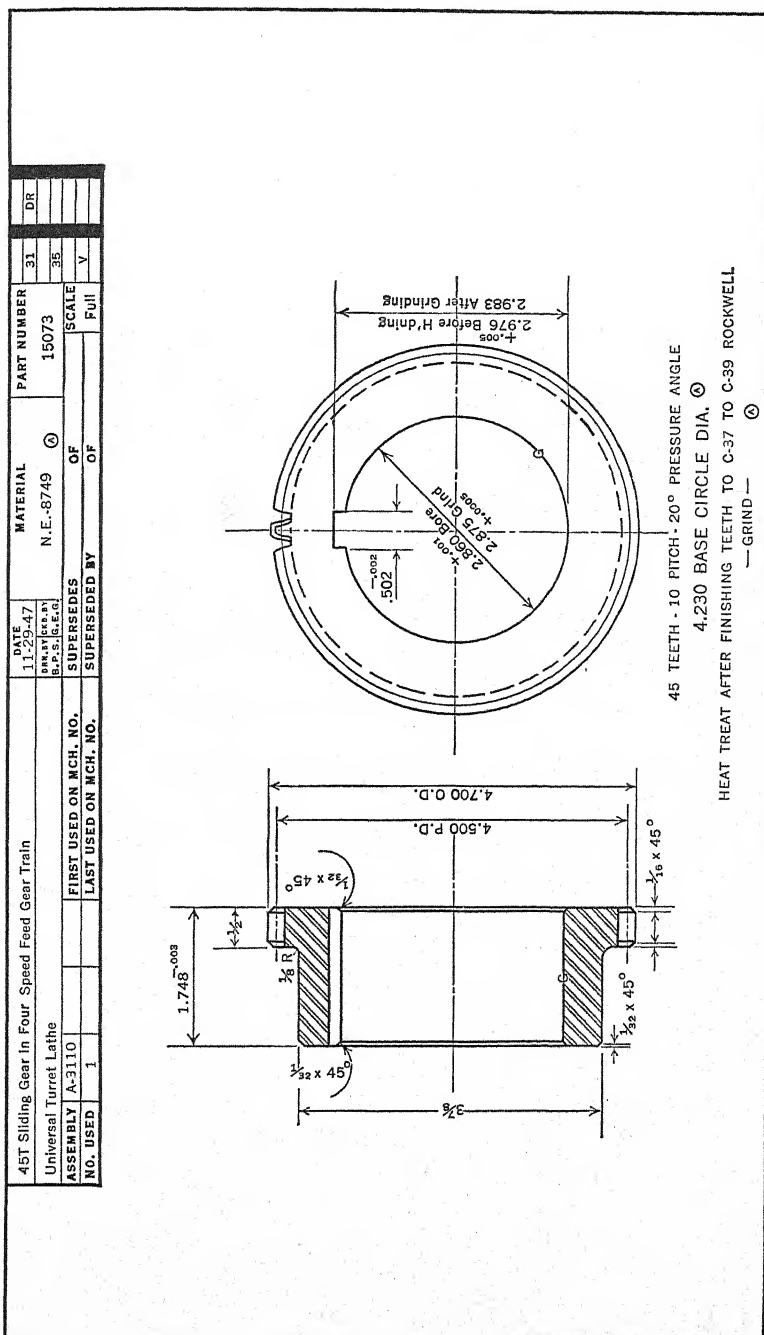


FIG. 230. Detail drawing of sliding gear, part number 15073.



these instructions are instructions in diagram form numbered for sequence of operation. For instance, 1/ is the first operation on the turret lathe, 2/ is the second, etc. These instructions also give the operator the part number of the tool that he is to use. For example, (525 TO) is the number of the tool to be used in the first position of the square turret. The speeds and feeds to be used are also given. For example,

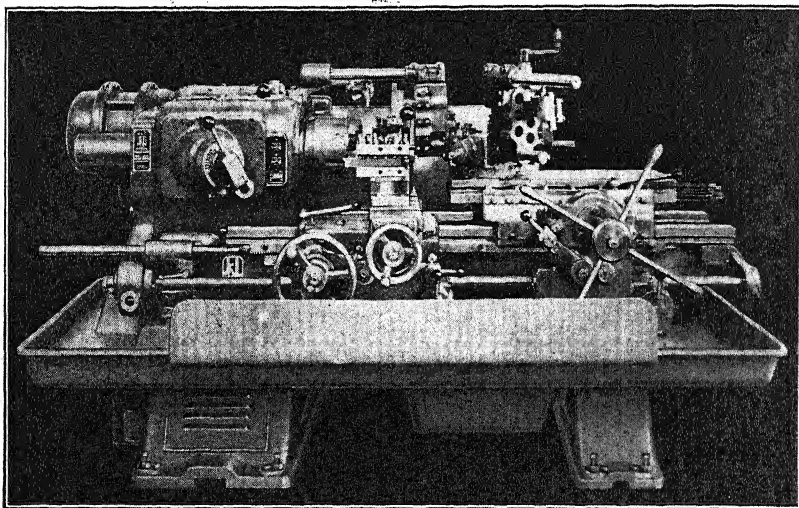


Fig. 231. Jones and Lamson universal turret lathe.

in the third position of the square turret, the operator is to use a spindle speed of 340 rpm and a feed of 0.011 inch per rpm.

The lower half of the sheet shows exactly how the standard time for the operation is computed. This portion of the sheet, which is kept in the time study department, is available for reference in case of possible complaint or error. In the left-hand corner of this section the setup time for each operation is shown. The general setup time is 16 minutes, this being an average setup. Underneath this figure the time is given for various operations incidental to the complete setup. In the column adjacent to this, time is given for setting stops. The fourth, fifth, and sixth columns show the computation of the actual cutting time. This computation includes the actual cutting time plus an incentive allowance. The next three columns give time allowed for miscellaneous handling and gauging. All handling and gauging time contains 15 per cent allowance for rest and personal time. The last two columns summarize the cutting and handling times, which



total 7.10 minutes. The 1.05 factor by which the cutting time in column six is multiplied to get the final time of 4.05 minutes is an allowance for resharpening dull tools.

**Motion-Picture Records.** Some complicated manual operations can be recorded best by motion pictures. In fact, it may be more economical in certain cases to make the record in this manner than to rely entirely on a written description of the job. On important operations, "before" and "after" motion pictures are frequently made for other purposes and of course may also serve as a supplement to the written standard practice. However, few companies as yet have seen fit to use motion pictures for standard-practice records in a general way.



## CHAPTER 19

### THE RELATION OF MOTION AND TIME STUDY TO WAGE INCENTIVES

During the last fifty years the emphasis in motion and time study application has been on the setting of time standards for use with wage incentives. Of course motion and time study has been used for improving methods and for standardization of conditions, but greatest interest and most extensive use have been for rate setting. The present trend, however, is toward a more nearly balanced program. Motion study is receiving considerable attention at the present time, and there is much evidence to show that this phase of motion and time study is as valuable to the manager as is the use of time study for wage incentives. Also, employees are more likely to react favorably to this broader program of motion and time study, particularly since motion study has as its primary object finding the easiest and most satisfactory way of doing work, which usually increases output without requiring the employee to increase his effort.

**Necessity for Measuring Labor Accomplishment.** Labor is an important factor in the cost of producing manufactured goods, and management must consider labor costs like all other costs in the operation of a business. It is management's job to see that its employees do not do useless and unnecessary work. All operations should be subject to careful analysis, and the easiest and best method for the individual operation should be found. Whenever possible, the work should be measured and the employee should be told what a standard day's work is for his job. In all these activities, management must never forget that each employee is a person and that he should be treated as such. If management hopes to gain and keep the interest and cooperation of its employees, management must make certain that every action of the company will benefit the individual worker. There is plenty of evidence to show that the worker's mental attitude, his morale, "will to work," and enthusiasm for the job and for the company are of real value to management; and wages alone, however large they may be,



will not necessarily produce these desirable attributes in a working force.

Most things of value are purchased by measure, that is, a price is paid for a number of units of a given commodity of a specified quality. For example, sugar is bought by the pound, cloth by the yard, and energy by the kilowatt-hour. When a single factor is to be measured, the unit of measurement deals only with that factor. Thus distance may be measured by units of length and contents by units of volume. When two factors are involved, however, as in electrical energy, both time and power must be included in the unit of measurement.

All work is largely a combination of mental and manual effort expended in a given period of time. Most factory work and much office work are largely manual, and it is this type of labor which is being considered in this book.

The results of work determine its value rather than the effort exerted. This is true whether a person works for himself or for someone else. It is the operator's productivity, his accomplishment, that largely measures his worth to his employer. Since accomplishment results from the application of effort and is influenced by both the duration and the intensity of effort, the unit of measurement of work done must include both quantity and time. Accomplishment can usually be measured most effectively in terms of quantity of work done per unit of time, that is, pieces per hour or tons per day. Ordinarily a standard of quality is specified, and only those units that meet the quality standard are considered as finished units.

Although some criticism has been directed at the principle of payment of labor in proportion to its productivity, there is much in favor of such a plan if properly administered. The greatest difficulty in the application of wage incentives is in the determination of the standard task. The answer to the question "What constitutes a standard day's work?" is very important indeed.

Motion and time study is the most accurate system known for measuring labor accomplishment. Although motion and time study is not a perfect tool it will, if applied by well-qualified and properly trained persons, give results that are satisfactory both to the employee and to the employer.<sup>1</sup>

<sup>1</sup> For criticisms of present-day motion and time study practices see:

(a) E. T. Cheyfitz, "More for Less," *Fortune*, Vol. 30, pp. 130-31, December, 1944.

(b) W. Gomborg, "Labor Examines Time Study Methods," *Industrial Engineer*, Vol. 4, No. 3, pp. 13-16, March, 1944; and "The Relationship between the



In past years, and unfortunately to some extent today,<sup>2</sup> rates have been set on the basis of (1) past performance of operators, (2) estimate by the supervisor or by an "estimator," and (3) overall time for a trial lot. These methods of "measuring" what should constitute a day's work are never satisfactory and should not be used. An elemental stop-watch time study carefully made by a competent analyst should be used in setting time standards. Of course the use of adequate standard data is also quite acceptable.

**Effects of Motion and Time Study and Wage-Incentive Applications on the Worker.** The two phases of motion and time study that concern the worker most are (1) improving the method of doing work and (2) setting a time standard as the basis for a wage incentive. These two functions affect the operator in distinctly different ways. Both tend to reduce unit labor cost to the employer mainly by reducing the man-hours required; consequently both tend to displace labor on a given operation. That is, if windows in the factory and office buildings can be washed in half the time formerly taken, through the use of a carefully planned method and a wage incentive, then only half as many window washers will be required on the payroll of the company as would otherwise be employed. In this respect motion and time study falls into the category with tools and machinery, which reduce labor costs because of their greater efficiency.

We all know that our high standard of living in this country has been attained because of our high labor productivity. We have steadily reduced the number of man-hours per acre needed to plant, cultivate, and harvest our crops. The number of man-hours of labor needed to mine a ton of coal has been cut in half during the last forty years, and the manufacturing industry has a continuous record of producing more with fewer man-hours. It has been fully demonstrated

Unions and Engineers," *Mechanical Engineering*, Vol. 65, No. 6, pp. 425-30, June, 1943; "A Trade Union Analysis of Time Study," Science Research Associates, Chicago, 1947.

(c) S. Miller, Jr., "Labor's Attitude toward Time and Motion Study," *Mechanical Engineering*, Vol. 60, No. 4, pp. 289-94, April, 1938.

(d) R. S. Uhrbrock, "A Psychologist Looks at Wage-Incentive Methods," American Management Association, *Institute of Management Bulletin* 15, 1935.

<sup>2</sup> A survey of 80 companies employing 50 to 15,000 factory workers showed that 95 per cent of the companies use time study for setting time standards as a basis for wage incentives. Thirteen per cent use past performance, 6 per cent make an estimate, and 3 per cent use other methods. The reason the percentage totals more than 100 is because some of the companies use more than one method. "Industrial Engineering Survey," *Industrial Engineering Report* 100, published by the University of Iowa, p. 3, 1946.



that in the long run every one benefits from increased productivity. Each organization should see to it that such general benefits are obtained without asking any one to work inordinately hard or without creating unemployment, even temporarily. In fact, some companies are guaranteeing to their employees that no one will be laid off as the result of the introduction of new machines, processes, or methods, or because of the installation of a wage-incentive system.

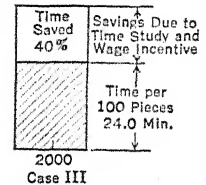
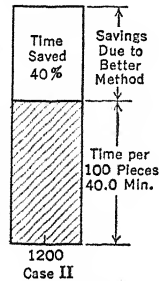
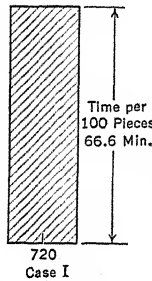
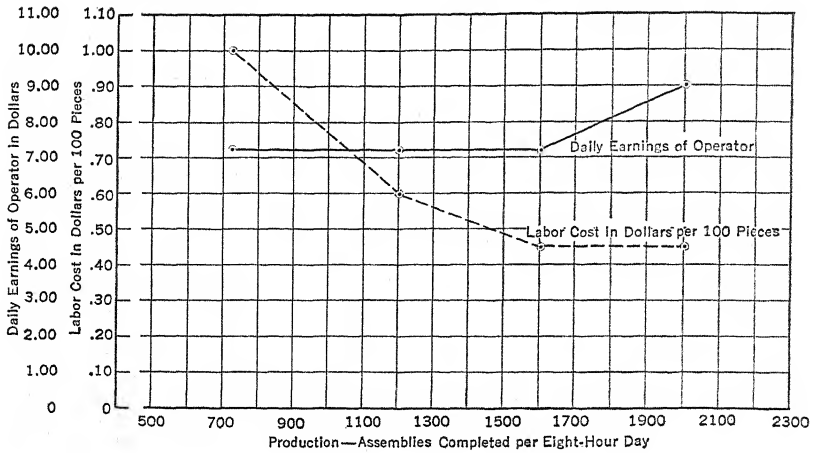
By the improvement of methods alone, the work is often made sufficiently easy so that with the same expenditure of energy the operator is able to produce more units per day. Thus, through the use of duplicate bins and the simple fixture for the assembling of the bolt and washers described on page 194, the operator was able to do a half more work in the same time. This phase of motion and time study permits the operator to do more work without asking that he use more energy.

In contrast, the second phase of motion and time study, that of setting a time standard to be used with a wage incentive, reduces man-hours by offering to pay the operator more wages if he will do more work in a given period of time. To earn this extra reward the operator produces more mainly through the elimination of idle time, through greater concentration on the job, and through greater expenditure of energy.

Perhaps an example is the best way to show the whole picture. This case will indicate not only how these two phases of motion and time study affect the employee through increase in earnings, but it will also show how it affects the employer through a decrease in the direct labor cost of the product. It will be assumed that no increase in wages is given to the operator when improvements in methods alone are made.

The operation is that of assembling a work-rest bracket for a bench grinder. The data in Fig. 232 show a 40 per cent saving in time from an improvement in the method of assembling the bracket. The operator worked without incentive in both Case I and Case II. That is, she was paid a flat hourly rate irrespective of the output. She exerted approximately the same physical effort and gave approximately the same mental attention in both cases. However, in Case I she made 720 assemblies per day, whereas in Case II she made 1200 assemblies per day. This increase in output resulted, not from working faster, but from a better arrangement of the work place and from the use of a special fixture which enabled the operator to use her hands to better advantage. She could do more work in the same time and with the same expenditure of energy because she could assemble a bracket with





## CASE I

*Method.* Assemble one piece at a time. Left hand holds bracket while right hand assembles parts. Method poor.

*Supervision.* Poor.

*Performance of Operator.* Poor.

*Method of Wage Payment.* Day work. Hourly rate = \$0.90. Daily earnings of operator = \$7.20.

*Average Production* taken from past records is 720 pieces for an 8-hour day. Average time per 100 pieces = 66.6 minutes.

*Average labor cost* per 100 pieces = \$1.00.

## CASE II

*Method.* Assemble two pieces at one time, using special fixture. Method good.

*Supervision.* Poor.

*Performance of Operator.* Poor.

*Method of Wage Payment.* Day work. Hourly rate = \$0.90. Daily earnings of operator = \$7.20.

*Average Production* taken from past records = 1200 per 8-hour day. Average time per 100 pieces = 40.0 minutes.

*Average Labor Cost* per 100 pieces = \$0.60.

## CASE III

*Method.* Assemble two pieces at one time, using special fixture. Method good.

*Supervision.* Good.

*Performance of Operator.* Good. Operator now on incentive.

*Method of Wage Payment.* Straight-piece rate with guaranteed minimum rate of \$0.90 per hour. Standard time per 100 pieces set by time study = 30.0 minutes. Piece rate per 100 pieces = \$0.45. Standard output per day = 1600 pieces. Average number of pieces actually produced per day by this operator = 2000. Average daily earnings of this operator = \$9.00.

*Average Labor Cost* per 100 pieces = \$0.45.

OPERATION: Assemble Work Rest Bracket for Bench Grinder

OPERATOR: Helen G. Meyers, No. 746231

BASE WAGE: 90 cents per hour—8-hour day—40-hour week

WAGE-INCENTIVE PLAN: Straight Piece Rate

Fig. 232. The relation of motion and time study to wage incentives.



fewer motions, with no tiring holding of parts, and with an easy rhythm which was not possible in Case I.

In Case III a time standard was set by means of a stop-watch time study and a piece rate was established for the operation. The operator now had the opportunity of earning more than her guaranteed base wage of \$7.20 per day. In fact, she was easily able to do 25 per cent more work than the standard, and in return for this extra performance she earned \$9.00 per day.

The increased output resulting from the application of the piece rate came because the operator "worked harder" than she did in Case II. That is, she worked more consistently through the day, eliminated idle time, took less personal time, and perhaps visited less frequently with her neighbors. She was at her bench ready to start work when the whistle blew and worked until quitting time, concentrating on the work she was doing during the entire day. Although it is likely that the operator used approximately the same motions in completing a cycle in Case III as in Case II, it is certain that she used more effort in Case III than in Case II. The incentive of greater pay for greater output was responsible for this. It is also likely that the operator was more fatigued at the end of the day in Case III than in Case II.

It is, therefore, apparent that increased output through improved methods ordinarily causes the operator no increase in fatigue. In fact, the improved method is usually easier, more satisfying, and less fatiguing than the original method. On the other hand, the application of a wage incentive usually causes the operator to work harder. The extent of the operator's exertion will depend upon his own inclination and his fitness for the job. With straight-piece rate or with a 100 per cent premium plan of wage payment, the reward is in direct proportion to the output.

For the employer the application of motion study reduced the direct labor cost 40 per cent, and the setting of the rate and the wage incentive reduced it another 40 per cent. The direct labor cost per 100 pieces in Case I was \$1.00, in Case II \$0.60, and in Case III \$0.45. This is shown graphically by the curve at the top of Fig. 232.

**Ways in Which Motion and Time Study and Wage Incentives Increase Output.** The question is frequently raised as to why there is often such a great difference between the output of a person paid on a day-work basis without production standards established for his job and the output of the same person after time standards have been set and an incentive system of wage payment is used.



There are three main reasons why motion and time study and a wage incentive installation may bring greater daily output among direct labor.

1. Improved work methods enable the operator to produce more with the same effort. In some organizations it is the practice to improve methods before beginning the time study work. Even if this procedure is not followed, it is still possible that some improvement in methods will result from preliminary work incident to time study.

In some plants, particularly those with poor supervision, we may find work done in a hit-or-miss manner, inadequate planning, lack of standardization, and little or no idea of what a day's work should be. In such plants, materials that vary from standard may force operators to work at a slow pace or to perform extra operations which may result in low output per hour. Delays may be caused by machines and equipment not being kept in good repair. Lack of work, delay in sharpening tools, and inadequate supervision may cause idleness on the part of the operator. Time study would reveal such inefficiencies, and a wage-incentive system would require that they be corrected. Standardization of materials, methods, tools, equipment, and working conditions *must always precede* the installation of a wage-incentive system. This is management's responsibility.

2. If each employee knows what a normal day's work is and if he is paid a bonus for work produced above the standard, he will in most cases on his own accord eliminate waste time within his control, such as late starting, early quitting, and unnecessary idleness during the day. Moreover, he will put pressure on management to eliminate causes of idle time beyond his control, such as shortage of material, machine breakdowns, and delays in sharpening tools.

For example, Fig. 233 shows graphically the results of an all-day production study of a short-cycle hand milling machine operation. This operator worked in a remote part of the plant, had little supervision on this particular operation, and on the day during which this study was made he lost 38.9 minutes because of late starting and early quitting and 32.9 minutes for other personal reasons. Although an operator on such work might possibly be allowed 10 per cent or 48 minutes per day for personal time and fatigue allowance, this operator actually took a total of 71.8 minutes or the 48 minutes allowed him and 23.8 minutes in addition. In most plants a financial incentive and a little encouragement are all that would be needed to persuade this operator to work during the 23.8 minutes that he lost.



A time standard would be set so that a qualified person working at a normal pace during 432 minutes ( $480 - 48 = 432$ ) of the day

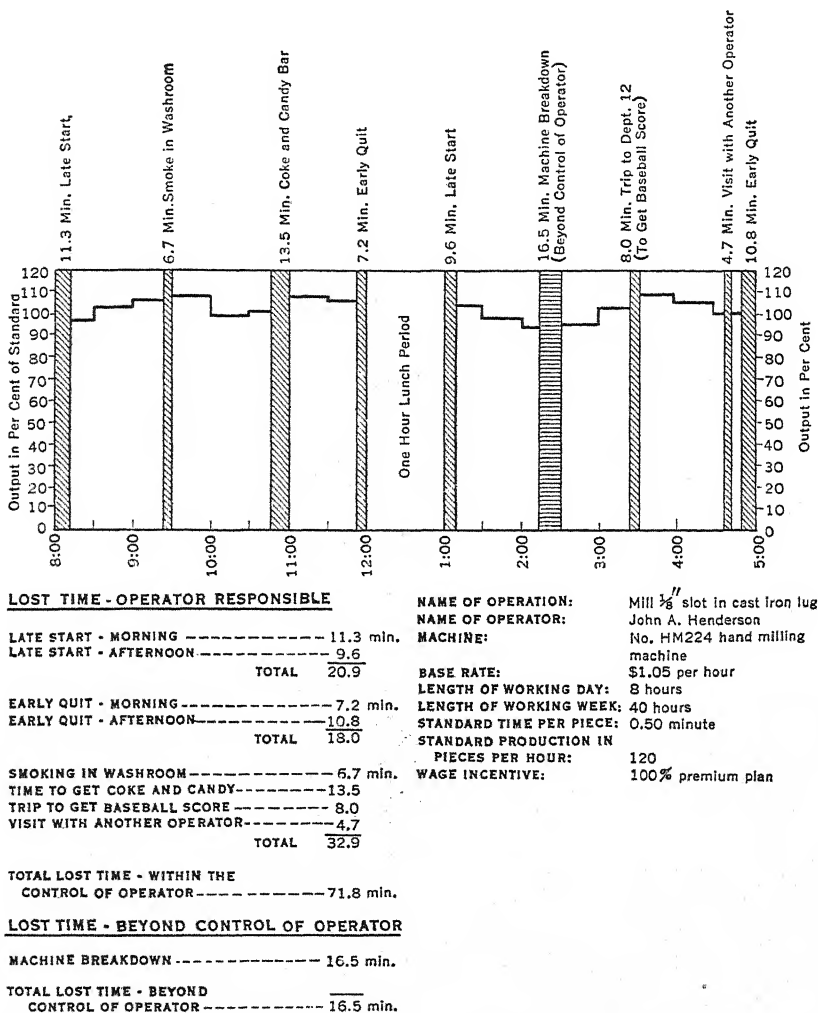


Fig. 233. Production curve for one day. Output is expressed in per cent, with 100 per cent equal to standard performance.

would produce 432 standard minutes of work. As the data in Fig. 233 show, during the time this man was actually working he produced at a pace averaging 102 per cent. However, he turned out only 799 pieces during the eight-hour day. Had he worked at this same pace of 102



per cent efficiency during the 432 minutes, he would have turned out 881 pieces. Of course the lost production that resulted from the 16.5-minute machine breakdown is beyond the control of the operator.

Some people prefer to work during some or all of the time allowed for personal needs and fatigue. When there are no fixed rest periods, the worker is of course paid for the output which he produces during this time. It should be pointed out that fatigue allowances are intended to permit the operator to relax and recuperate during the working day, and it is expected that most workers will take time out for this purpose. However, some workers do not seem to need such time for rest and prefer to work straight through the day with only the noon hour off.

3. Since the work standard is set so that qualified operators can easily exceed the standard and thus earn additional compensation, the wage incentive serves to encourage workers to increase their speed and thus turn out more work per hour than they would normally. If this operator's (see Fig. 233) efficiency was 102 per cent during his working time when paid on a day-work basis, it is to be expected that he would work at a faster pace if he receives extra pay for all work produced beyond the standard for this job.

Nearly every person finds that he can exceed the hourly output defined as "normal performance," and the average output of a group of qualified operators working on incentives usually exceeds normal by 15 to 35 per cent. A study of 80 companies showed that the average output was 22 per cent above normal.<sup>3</sup>

Time study serves to establish the correct work standard, and the wage-incentive system serves to pay the worker for the extra output he produces beyond the standard. The effort that an employee chooses to exert at a given time or on any particular day is entirely a personal matter with him. Each person is guaranteed his hourly rate of pay irrespective of his output. In this example (see Fig. 233), this guaranteed rate was \$1.05 per hour or \$8.40 for the 8-hour day.

**A Motion and Time Study and Wage Incentive Application.** The demand for a new product often exceeds that predicted for it, and in order to satisfy the demand an extra shift is used or extra machines are purchased with little or no change being made in the production methods. Eventually, however, a more careful analysis of each operation will be made, and some organizations make such an analysis at

<sup>3</sup> "Industrial Engineering Survey," *Industrial Engineering Report* 100, published by the University of Iowa, p. 3, 1946.



the time they put the work on incentive. The following case gives a day-by-day record of steps that were taken and the results that were obtained on one job. The operation was a rather complicated assembly, involving some gauging and adjustment. The job had been running for one week on day work, and the average output of the operator was around 22 pieces per hour. (See Fig. 234.)

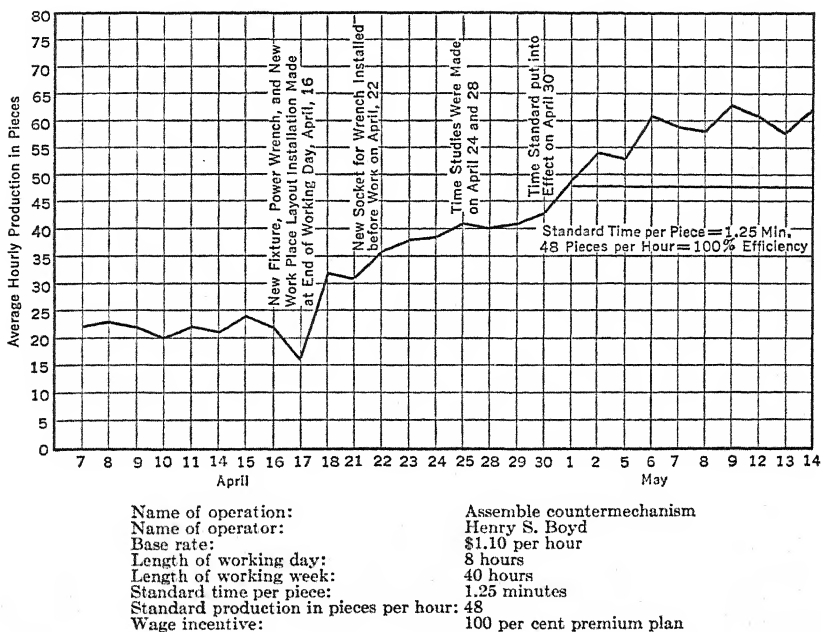


Fig. 234. Production curve showing effects of the installation of a wage incentive. Output is expressed in pieces per hour.

A new method was suggested by the foreman, and a special fixture was made and installed at the end of the working day on April 16. This new fixture and the new work-place layout enabled the operator to make the assemblies faster than formerly, but the socket wrench gave trouble. The operator liked the new layout but complained that the socket on the power wrench was too small for the nuts. Production dropped to 16 pieces per hour mainly because of trouble with the wrench. After work on April 17, the foreman tried to have the socket made larger but the next day the operator still had some trouble. A new socket was ordered. Production, however, jumped to 32 pieces per hour on April 18. On the morning of April 22 a new socket was installed on the power wrench, which made it easier to use, and this in-



creased output to 36 pieces per hour. The output gradually increased to around 40 pieces per hour. The operator was somewhat amazed at the amount of work he was turning out each day. A time study was made of the job on April 24 and April 28. The standard was set at 48 pieces per hour, and the new standard was put into effect on April 30. The next day the average hourly production was 49 pieces per hour, and the following day it went up to 54 pieces per hour. Production for this operation stabilized at around 58 to 60 pieces per hour, which represents an efficiency of 120 to 125 per cent. At this level of production the operator earned a bonus of 20 to 25 per cent; thus he earned 20 to 25 per cent more money than it had been possible for him to earn prior to the installation of the wage incentive.



## CHAPTER 20

### STOP-WATCH TIME STUDY—TIME STUDY EQUIPMENT— MAKING THE TIME STUDY

Stop-watch time study is the most commonly used method of measuring work in industry today. However, as will be explained later, there is a definite place for synthetic time standards established by using standard data for elements and for carefully defined motions and combinations of motions.

Each of the several different methods of determining the standard time required to do a given task will be presented in this and the following seven chapters. This chapter describes the equipment used and explains how a stop-watch time study is made. Chapters 21 and 22 show how the rating factor, allowances, and the time standard are determined. Chapters 23, 24, and 25 deal with elemental time data and formulas for setting time standards synthetically, and Chapters 26 and 27 show how standard time values for combinations of hand motions may also be used for obtaining the standard time for an operation without the use of a stop watch.

**Definition of Time Study.** Time study is used to determine the time required by a qualified person working at a normal pace to do a specified task. This is the third part of the definition of motion and time study which appears on page 1. It should be noted that while motion study is largely analysis, time study involves measurement. Time study is used to measure work. The result of time study is the time in minutes that a person suited to the job and trained in the specified method will need to perform the job if he works at a normal or standard tempo. This time is called the *standard time* for the operation.

**Uses for Stop-Watch Time Study.** Although stop-watch time study has had greatest use for determining time standards in connection with wage-incentive plans, time study is now being used for a number of other purposes. Stop-watch time study may be used for:

1. Determining schedules and planning work.
2. Determining standard costs and as an aid in preparing budgets.



3. Estimating cost of a product prior to manufacturing it. Such information is of value in preparing bids and in determining selling price.
4. Determining machine effectiveness, number of machines which one person can operate, number of men needed on a gang, and as an aid in balancing assembly lines and work done on a conveyor.
5. Determining time standards to be used as a basis for the payment of a wage incentive to direct labor.
6. Determining time standards to be used as a basis for the payment of indirect labor, such as handlers and setup men.

### TIME STUDY EQUIPMENT

The equipment needed for time study work consists of timing devices and auxiliary equipment. The devices for measuring time are (1) stop watch, (2) motion picture camera (with constant speed motor-

drive or with a microchronometer in the picture to indicate time), and (3) time-recording machine. The auxiliary equipment consists of observation board, tachometer, and slide rule.

**Decimal Stop Watches.** The decimal-minute watch and the decimal-hour watch are the only two types of stop watches that are used for time study work, and the first is used more widely than the second. The stop watch is by far the most widely used timing device for time study work. The camera and the time-recording machine are used only in special cases for time study.

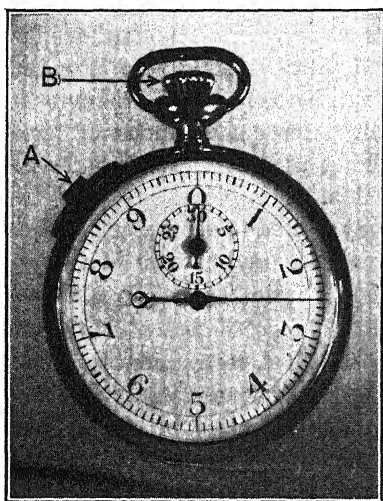


FIG. 235. Decimal-minute stop watch.

The decimal-minute stop watch (see Fig. 235) has the dial divided into 100 equal spaces, each of which represents 0.01 minute, the hand making one complete revolution per minute. A smaller dial on the watch is divided into 30 spaces, each of which represents 1 minute, the hand making one complete revolution in 30 minutes. The hands of the watch are controlled by the slide *A* and the winding stem *B*, as



shown in Fig. 235. The starting and stopping of the watch are controlled by the slide. It is possible to stop the hand at any point and then start it again from that position. Pressure on the top of the stem *B* returns the hand to zero, but it starts off immediately upon releasing the stem. The hand may be held at zero either by holding the stem down or by pushing the slide *A* away from the stem.

The decimal-hour stop watch is like the decimal-minute watch in design and operation. However, it has the dial divided into 100 spaces, each of which represents 0.0001 hour, the hand making 100 revolutions per hour. The small dial on the watch is divided into 30 spaces, each of which represents 0.01 hour, the hand making  $3\frac{1}{3}$  revolutions per hour. The principal advantage of this watch is that the readings are made directly in fractions of an hour, which is the common unit of time measurement in industry. The chief disadvantage of the decimal-hour watch is that it is more difficult to handle four decimal places than two decimal places. This is particularly true in recording stop-watch data on the observation sheet.

The split-second stop watch is not recommended and is seldom used for stop-watch time study work.

**The Motion-Picture Camera for Time Study Work.** The time for the elements of an operation can be obtained from the motion pictures of the operation made with a synchronous motor-driven motion-picture camera (see Fig. 236) of known speed, or by placing a microchronometer in the picture when the operation is filmed. The method of making such pictures has been explained in Chapter 11.

The camera speed most frequently used is 1000 frames per minute, which permits the measurement of time in thousandths of a minute. A motion picture of an operation forms a permanent record of the method used as well as the time taken for each element of the operation. Moreover, the film may be projected at the exact speed at which the picture was made, and a check may be made of the operator's performance. In other words, the operator's speed or tempo may be rated—that is, related to standard performance.

**Time-Recording Machines.** For some years machines have been used to a limited extent in this country and abroad for recording time on paper tape moving through the machine at uniform velocity.

The time-recording machine consists of a small box through which a paper tape is drawn by an electric motor at a uniform velocity of 10 inches per minute. The tape has a printed scale in tenths of an inch, and therefore one division on the tape equals 0.01 minute. The time study machine has two keys which, when depressed, print marks on



the tape. The beginning of an element is ordinarily recorded by pressing both the keys, and the end of the element is recorded by pressing one key. It is also necessary to have access to electric power circuits which have the correct voltage to operate the recording machine motor. This time-recording machine may be used instead of a stop watch, and

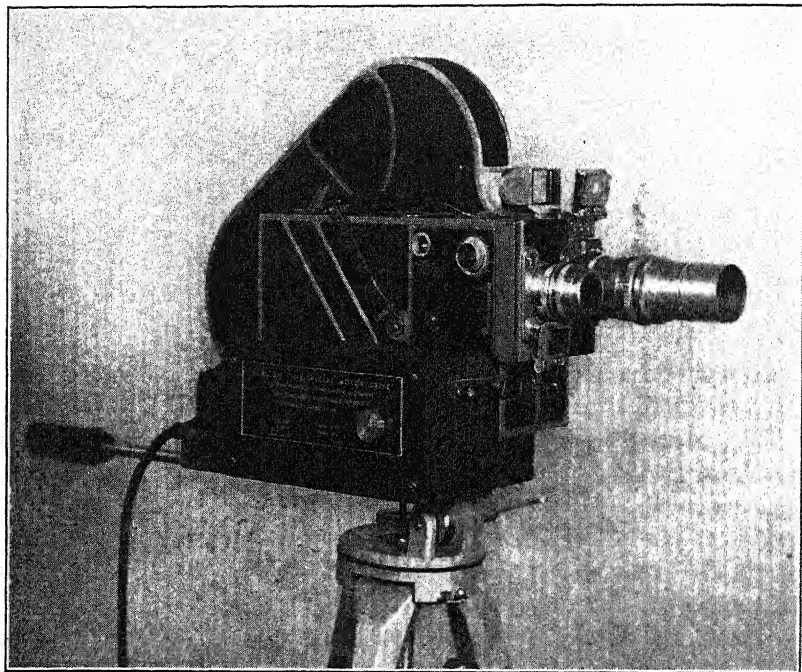


FIG. 236. Motion-picture camera with synchronous motor drive gives a constant speed of 1000 frames per minute.

it enables the analyst to measure shorter elements than he could with a stop watch. The machine seems to be most useful where short cycles are to be timed and where the operator follows a given routine without the introduction of many foreign elements.

The Servis recorder is a spring-driven instrument which records time on a wax-coated paper disk by means of a stylus attached to a small pendulum within the instrument. The recorder is fastened to a machine or piece of equipment, and the vibration of the machine causes the stylus to record "working time" on the disk. When the machine stops, the pendulum stops vibrating and the instrument records "idle time" on the disk. The disk is divided into hours and minutes and in-



icates the length of working time or idle time and also the time of day when each occurs. The instrument is most valuable for recording delays and lost time and is not used for making time studies.

**Observation Board.** A lightweight board, slightly larger than the observation sheet, is used to hold the paper and the stop watch. There

**OBSERVATION SHEET**

Study No. \_\_\_\_\_

OPERATION \_\_\_\_\_ Op. No. \_\_\_\_\_

PART NAME \_\_\_\_\_ Part No. \_\_\_\_\_

Machine Name \_\_\_\_\_ Machine Number \_\_\_\_\_

Operator Name & No. \_\_\_\_\_ Dept. \_\_\_\_\_

Experience on Job \_\_\_\_\_ Date \_\_\_\_\_

Material \_\_\_\_\_

Begin	Finish	Elapsed	Units Finished										Elapsed Time	
			Speed	Feed	1	2	3	4	5	6	7	8		9
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														

Selected Time \_\_\_\_\_

Normal Time \_\_\_\_\_

Personal Allowance \_\_\_\_\_

Fabric Allowance \_\_\_\_\_

Total Allowance \_\_\_\_\_

Standard Time \_\_\_\_\_

Tools, Jigs, Gauges: \_\_\_\_\_

Timed By \_\_\_\_\_

FIG. 237. Observation board with observation sheet for recording data taken by the repetitive method.

are many different arrangements, but it seems best to have the watch mounted rigidly somewhere near the upper right-hand corner of the board and the observation sheets held in place by some form of clamp at the side or top of the board. The observation board shown in Fig. 237 is a form commonly used. Since the analyst, in most cases, must



record the data while standing, it is desirable to have his watch and paper arranged as conveniently as possible.

While taking a stop-watch study the observer should hold the board against his body and the upper left arm in such a way that the watch can be operated by the thumb and index finger of the left hand. The observer holds the board with his left hand and arm, leaving his right hand free to record the data.

By standing in the proper position relative to the work being observed, and by holding the board so that the dial of the watch falls in the line of vision, the observer can concentrate more easily on the three things demanding his attention, namely, the operator, the watch, and the observation sheet.

The observation sheet is a printed form with spaces provided for recording information about the operation being studied. This information usually includes space for recording a detailed description of the operation, space for the name of the operator, name of the time study man, date and place of study. The form also provides space for recording stop-watch readings for each element of the operation, space for recording performance ratings of the operator, and space for computations. Space may be provided for a sketch of the work place, a drawing of the part and specifications of the material, jigs, gauges, and tools.

Observation sheets differ widely as to size and arrangement, although a sheet  $8\frac{1}{2}$  inches by 11 inches in size is widely used, mainly because of the ease in binding and filing. The observation sheets shown in Figs. 238, 248, and 252 have proved to be satisfactory in industries manufacturing a diversified line of products. Some organizations find it convenient to supplement the observation sheet with a separate computation sheet (see Fig. 254) and a supplementary sheet containing a more complete description of each element. (See Fig. 257.)

**Other Equipment.** A speed indicator, or a tachometer, is needed where machine-tool operations are studied. It is a very good rule for the analyst to check speeds and feeds in making a stop-watch study even though the machine has a table attached which gives this information for each setting of the speed and feed-control levers. Experience has shown that actual machine speeds do not always correspond with those on the manufacturer's tables because of variations in line-shaft speeds, changes in gearing, and other alterations of the machine that may have been made after the machine left the factory. If many different studies of the equipment are to be made, it is best to



check all speeds and feeds and prepare a new chart to replace the one on the machine if it is not correct.

The ordinary slide rule is recommended as a valuable aid and time saver to every motion and time study analyst. Special slide rules may be purchased or constructed and used to advantage in connection with certain kinds of work.

### MAKING THE TIME STUDY

The exact procedure used in making stop-watch time studies may vary somewhat, depending upon the type of operation being studied and the use that is to be made of the data obtained. These six steps, however, are usually required:

1. Securing and recording information about the operation and operator being studied.
2. Dividing the operation into elements and recording a complete description of the method.
3. Observing and recording the time taken by the operator.
4. Rating the operator's performance.
5. Determining the allowances.
6. Determining the time standard for the operation.

**Request for a Time Study.** A time study is not made unless an authorized person requests such a study. Usually it is the foreman who requests that a study be made although the plant manager, chief engineer, production control supervisor, cost accountant, or other member of the organization may make such a request.

If a time standard is to be established on a new job for wage-incentive purposes, it is the foreman's responsibility in most plants to make certain that the operation is running satisfactorily before requesting the study. He should also see that the operators have thoroughly learned the job and that they are following the prescribed method. The foreman should inform the operators in advance that a time study is to be made, stating the purpose of the study.

Incidentally, stop-watch time studies should be made only by members of the time study department. Unauthorized persons should not be permitted to make time studies even though they are not for wage-incentive purposes.

**Is the Job Ready for Time Study?** After a request for a time study has been received by the time study department and a time study analyst has been assigned to make the study, he should go over the job



with the foreman of the department. As they discuss each element of the operation, the analyst asks himself the question, "Is this operation ready for a time study?"

The time standard established for a job will not be correct if the method of doing the job has changed, if the materials do not meet specifications, if the machine speed has changed, or if other conditions of work are different from those that were present when the time study was originally made. The time study man therefore examines the operation to be studied with the purpose of suggesting any changes that he thinks should be effected before the time study is made.

Although the foreman may have set up the job originally or he may have checked the method with the process engineer who set it up, the time study analyst should question each phase of the work, asking such questions as:

1. Can the speed or feed of the machine be increased without affecting optimum tool life or without adversely affecting quality of the product?
2. Can changes in tooling be made to reduce the cycle time?
3. Can materials be moved closer to the work area to reduce handling time?
4. Is the equipment operating correctly, and is a quality product being produced?
5. Is the operation being performed safely?

In fact, it is expected that the time study man will be trained in motion study and that he will bring all his knowledge in this field to bear on the operation he is about to time. Any suggested changes that the foreman wishes to adopt should be made before the study is started. Of course the foreman makes the decision as to the way the job is to be done, but the analyst and the foreman should discuss each element of the operation and should agree that the operation is ready for a time study. Standardization of the work has been discussed at length in the preceding chapters and it has been emphasized that all standardization should precede the actual setting of the time standard. The extensiveness of this work has been indicated in Table I on page 18 as ranging from the very elaborate Type A investigation requiring much time and considerable expense to the Types D and E requiring but a cursory analysis and a general check for methods.

If it should be decided that a major change in the operation is to be made and if considerable time will be required to put the new method into effect, it might be wise to make a time study of the present method



and then, after the improvements are installed, re-study the job and set a new time standard. If only minor changes are contemplated it is usually advisable to complete such changes before making a time study of the job.

**Making the Stop-Watch Study.** Those phases of stop-watch time study that can be carried out at the time and place of the performance of the operation will be described in this and the following chapter. They are obtaining and recording necessary information, dividing the operation into subdivisions or elements, listing these elements in proper sequence, timing them with the stop watch and recording the readings, noting and recording the operator's tempo or performance level, and making a sketch of the part and of the work place.

**Recording Information.** All information asked for in the heading of the observation sheet should be carefully recorded. This is important because time studies hastily and incompletely made are of little value. The first place to practice thoroughness is in filling in all necessary information for identification. A study may be practically worthless as a record or as a source of information for standard data and formula construction a few months after it has been made because the person who made the study has forgotten the circumstances surrounding it. Ordinarily, the necessary information concerning the operation, part, material, customer, order number, lot size, etc., can be obtained from the route sheet, bill of material, or drawing of the part.

A sketch of the part should be drawn at the bottom or on the back of the sheet if a special place is not provided. A sketch of the work place should also be included showing the working position of the operator, location of the tools, fixtures, and materials. Specifications of the materials being worked upon should be given and a description of the equipment being used should be recorded. Ordinarily the trade name, class, type, and size of the machine are sufficient description. If the machine has an identification number assigned to it, the number should be included. Accurate record should be made of the number, size, and description of tools, fixtures, gauges, and templets. The name and number of the operator should be recorded, and the time study should be signed by the time study man.

**Dividing the Operation into Elements and Recording a Description of the Method.** The standard time for an operation applies only to that particular operation; therefore a complete and detailed description of the method must be recorded on the observation sheet or on auxiliary sheets to be attached to the observation sheet. The importance of this description cannot be overemphasized. At any time



after the standard has been set for a job the time study department may be asked to determine whether the operator is performing the job in the same way it was being performed when the time study was originally made. The information contained on the observation sheet is the most complete description of the method that the time study department has available for such a check.

**Reasons for Element Breakdown.** Timing an entire operation as one element is not satisfactory, and an overall study is no substitute for a time study. Breaking the operation down into short elements and timing each of them separately are an essential part of stop-watch time study.

1. One of the best ways to describe an operation is to break it down into definite and measurable elements and describe each of these elements separately. Those elements of the operation that occur regularly are usually listed first and then all other elements that are a necessary part of the job are described. It is sometimes desirable to prepare a detailed description of the elements of an operation on a separate sheet and attach it to the observation sheet. The beginning and end points for each element may be specifically indicated. (See page 375; also Fig. 257.) Very often the elements taken from the time study can be used as the "Standard Practice" for the operation (see Fig. 291). Such a list of elements also may be used for training new operators on the job.
2. Standard time values may be determined for the elements of the job. Such element time standards make it possible to determine synthetically the total standard time for an operation. (See page 391.)
3. A time study may show that excessive time is being taken to perform certain elements of the job or that too little time is being spent on other elements. This latter condition sometimes occurs on inspection elements. Also the analysis of an operation by elements may show slight variations in method that could not be detected so easily from an overall study.
4. An operator may not work at the same tempo throughout the entire cycle. A time study permits separate performance ratings to be applied to each element of the job.

When time studies are to be made of a new product or of a new type of work, a careful analysis should be made of all variables of the work that are likely to occur. It is desirable to establish element time stand-



ards as soon as possible and such standards can be obtained more quickly if the general framework of the standards is prepared before any time studies are made. It is especially important to prepare a standard definition of elements so that these same elements may be used in all time studies.

**Rules for Dividing an Operation into Elements.** All manual work may be divided into fundamental hand motions or therbligs, as has already been explained. These minute subdivisions are too short in duration to be timed with a stop watch. A number of them, therefore, must be grouped together into elements of sufficient length to be conveniently timed.

Three general rules should be borne in mind in dividing an operation into elements:

1. The elements should be as short in duration as can be accurately timed.
2. Handling time should be separated from machine time.
3. Constant elements should be separated from variable elements.

To be of value a stop-watch study must be a study of the elements of the operation and not merely a record of the total time required per cycle to do work. If elements are too short, however, it is impossible to time them accurately. Elements of 0.03 or 0.04 minute are perhaps as short as can be conveniently measured with a stop watch.

In machine work it is desirable to separate the machine time, that is, the time that the machine is doing work from the time during which the operator is working. There are several reasons for this. Where power feeds and speeds are used on the machine it is possible to calculate the time required for the cut and thus check the actual stop-watch data when the machine time is kept separate. Also the beginning and the end of a "cut" are excellent beginning and ending points for an element. Where elemental time standards and formulas are to be developed it is essential that machine time be separated from handling time. The reasons for this separation will be explained in Chapter 23.

The elements of a cycle that are constant should be separated from those that are variable. The term "constant elements" refers to those elements that are independent of the size, weight, length, and shape of the piece. For example, in soldering seams of tin cans made by hand, the time to touch the iron to the bar of solder is a constant whereas



the time to solder the side seam on the can is a variable, varying directly with the length of the seam.

The analyst trained in the micromotion study technique will find it relatively easy to decide upon the elements of the operation because they are merely combinations of fundamental motions. The analyst without such training should see that the elements begin and end at well-defined points in the cycle. These points will have to be memorized by the analyst so that he will always read his watch at exactly the same place in the cycle; otherwise the time for the elements would be incorrect.

Each element should be stated concisely and recorded on the sheet in the space provided. It is sometimes advisable to use symbols to represent elements that are often repeated. In fact, in some industries a standard code of symbols is prepared and used by all time study observers. In either case the meaning of the symbols should appear on each observation sheet.

**Taking and Recording the Data.** The three most commonly used methods of reading the stop watch are (1) continuous timing, (2) repetitive timing, and (3) accumulative timing. The first two methods have much wider use than the last one.

*Continuous Timing.* In the continuous method of timing the observer starts the watch at the beginning of the first element and permits it to run continuously during the period of the study. (See Fig. 238.) The observer notes the reading of the watch at the end of each element and records this reading on the observation sheet opposite its name or symbol. Figure 248 illustrates the continuous method of timing. The operation of "Make Core for Crank Frame" was divided into four elements. The observer started his watch at the beginning of the first element, read it at the end of the first element, and recorded the reading in vertical column 1 on the lower line. In a similar manner the watch was read at the end of each element, and the readings for the first cycle were recorded in column 1. The second cycle was then timed and the data recorded in the second vertical column, etc.

The time for each element was later determined by subtraction. (See Fig. 239.) Thus, for the first element, .09 ( $.09 - 0 = .09$ ) minute was placed in the upper line opposite element 1. In a similar way for the second element, .06 ( $.15 - .09 = .06$ ) minute was placed in the first vertical column opposite the second element.

*Repetitive Timing.* In the repetitive or snap-back method the hands of the watch are snapped back to zero at the end of each element. At



OBSERVATION SHEET																			
SHEET 1 OF 1 SHEETS					DATE 1-30-48														
OPERATION Drill $\frac{1}{4}$ " Hole					OP. NO. D-20														
PART NAME Motor Shaft					PART NO. MS-267														
MACHINE NAME Avey					MACH. NO. 2174														
OPERATOR'S NAME & NO. S.K. Adams 1347					MALE <input checked="" type="checkbox"/> FEMALE <input type="checkbox"/>														
EXPERIENCE ON JOB 18 Mo. on Sens. Drill					MATERIAL S.A.E. 2315														
FOREMAN H. Miller					DEPT. NO. DL 21														
BEGIN 10:15	FINISH 10:33		ELAPSED 23	UNITS FINISHED 20	ACTUAL TIME PER 100 115		NO. MACHINES OPERATED 1												
ELEMENTS			SPEED	FEED		1	2	3	4	5	6	7	8	9	10	SELECTED TIME			
1. Pick Up Piece and Place in Jig					T	.12	.11	.12	.13	.12	.10	.12	.12	.14	.12				
					R	.12	.29	.39	.54	.66	.77	.92	8.01	14	.32				
2. Tighten Set Screw					T	.13	.12	.12	.14	.11	.12	.12	.13	.12	.11				
					R	.25	.41	.51	.68	.77	.89	7.04	.14	.26	.43				
3. Advance Drill to Work					T	.05	.04	.04	.04	.05	.04	.04	.04	.03	.04				
					R	.30	.45	.55	.72	.82	.93	.08	.18	.29	.47				
4. DRILL $\frac{1}{4}$ " HOLE			950	H	T	.57	.54	.56	.57	.54	.58	.52	.53	.59	.56				
					R	.87	.99	3.11	4.23	5.36	6.51	.60	.71	.88	11.03				
5. Raise Drill from Hole					T	.04	.03	.03	.03	.03	.03	.03	.03	.04	.03				
					R	.91	2.02	.14	.26	.39	.54	.63	.74	.92	.06				
6. Loosen Set Screw					T	.06	.06	.07	.06	.06	.06	.06	.06	.07	.08				
					R	.97	.08	.21	.32	.45	.60	.69	.80	.99	.14				
7. Remove Piece from Jig					T	.08	.09	.08	.08	.09	.08	.07	.08	.09	.07				
					R	1.05	.17	.29	.40	.54	.63	.76	.88	10.08	.21				
8. Blow Out Chips					T	.13	.10	.12	.14	.13	.12	.13	.12	.12	.11				
					R	.18	.27	.41	.54	.67	.80	.89	9.00	.20	.32				
9.					T														
					R														
10. (1)					T	.12	.11	.13	.14	.12	.12	.11	.13	.12	.12	.12			
					R	1.44	.56	.69	.82	.87	17.01	18.09	.21	.31	.42				
11. (2)					T	.12	.14	.12	.11	.12	.10	.13	.15	.12	.11	.12			
					R	.56	.70	.81	.93	.99	.11	.22	.36	.43	.53				
12. (3)					T	.04	.04	.04	.03	.04	.04	.04	.04	.04	.04	.04			
					R	.60	.74	.85	.96	16.03	.15	.26	.40	.47	.57				
13. (4)					T	.64	.53	.55	.52	.57	.54	.50	.53	.55	.54	.54			
					R	12.14	13.27	14.40	15.48	.60	.69	.76	.93	21.02	22.11				
14. (5)					T	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03	.03			
					R	.17	.30	.43	.51	.63	.72	.79	.96	.05	.14				
15. (6)					T	.06	.06	.06	.07	.06	.06	.06	.06	.05	.06	.06			
					R	.23	.36	.49	.58	.69	.77	.85	20.02	.10	.20				
16. (7)					T	.08	.08	.09	.08	.08	.07	.08	.06	.08	.08	.08			
					R	.31	.44	.58	.66	.77	.84	.93	.08	.18	.28				
17. (8)					T	.14	.12	.10	.09	.12	.14	.15	.11	.12	.12	.12			
					R	.45	.56	.68	.75	.89	.98	19.08	.19	.30	22.40				
18.					T											1.11			
					R														
SELECTED TIME 1.11		RATING 100%		NORMAL TIME 1.11		TOTAL ALLOWANCES 5%		STANDARD TIME 1.17											
										TOOLS, JIGS, GAUGES: Jig No. D-12-33 Use H.S. Drill $\frac{1}{4}$ " Diam. Hand Feed Use Oil - S4  TIMED BY J.B.M.									

Fig. 238. Stop-watch time study of a drilling operation made by the continuous method.



the beginning of the first element the observer snaps the hand back to zero by pressing the stem of the watch. The hand moving forward instantly begins to measure the time for the first element. At the end of the first element the observer reads the watch, snaps the hand back to zero, and then records this reading. In a like manner he times the rest of the elements. This method of timing gives the direct time without subtractions, and the data are recorded on the observation sheet as read from the watch. (See Fig. 252 on page 378.)

Some people think that there is a tendency for the observer to neglect to time and record delays, foreign elements, or false motions of

STUDY NO. 8765			
ELEMENTS	SPEED	FEED	1
1. Fill core box with 3 handfuls of sand. Press sand down each time.			.09
			0.9
2. Press sand down with one trowel stroke. Strike off with one trowel stroke.			.06
			.15
3. Get and place plate on core box, turn over, rap, and remove box.			.13
			.28
4. Carry plate with core 4 feet. Dispose on oven truck.			.04
			.32

Fig. 239. Part of observation sheet for operation "Make Core for Crank Frame." The watch readings and the subtracted times for the first cycle are shown. See

Fig. 248 for complete study.

the operator by simply holding down the stem of the watch. This is not a valid criticism of repetitive timing as the observer should be taught to time and record *all elements* that occur during the study. The main advantage of the repetitive method over the continuous method is that the time for each element is visible on the observation sheet and the time study man can see the variations in time values as he makes the study.

**Accumulative Timing.** The accumulative method of timing permits the direct reading of the time for each element by the use of two stop watches. These watches are mounted close together on the observation board (see Fig. 240) and are connected by a lever mechanism in such a way that, when the first watch is started, the second watch is automatically stopped. When the second watch is started the first is stopped. The watch may be snapped back to zero immediately after it is read, thus making subtractions unnecessary. The watch is read with greater ease and accuracy since the hands of the watch are not in motion at the time it is read.

**Recording the Stop-Watch Readings.** To the uninitiated it may seem difficult for the observer to do the several things required of him



in such quick succession, viz., observe the operator, read the watch, and record the data on the observation sheet; but it is easily possible after a little experience.

A distinctive sound frequently accompanies the beginning and the ending of the element. Thus, in the study of the drilling operation (Fig. 238), as the shaft is dropped into place in the jig there is a

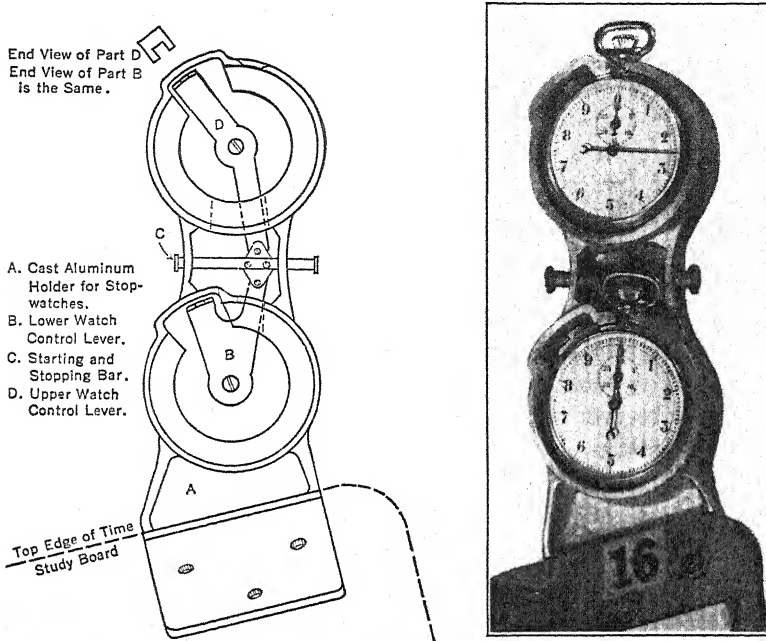


FIG. 240. Two stop watches connected by suitable linkage for *accumulative* method of timing.

metallic click which denotes the end of the first element. Such sounds aid the observer in taking his readings, and he soon learns to make use of them.

The general policy of carefully timing every part of the operation should be insisted upon. If, for example, every fifth or every tenth piece is gauged, such information should be included on the observation sheet and a sufficient number of readings of this element should be made to include it in the time for the operation. The time for the element would, of course, be divided by 5 or 10, as the case might be, in order to prorate the gauging time.

Such elements as "change tools," "blow chips out of jig," "move finished parts," "replace empty tote box," "lubricate die," and the like



should be considered specific parts of the operation and should be timed as such. In timing elements that occur infrequently it is necessary to get a sufficient number of watch readings and also to obtain data as to the frequency of occurrences of such elements so that the time can be prorated.

When foreign elements occur they should be timed and recorded on the observation sheet. These elements may or may not be included in the time standard, depending upon their nature. By foreign elements is meant elements that do not occur regularly in the cycle, such as accidentally dropping a wrench or piece of material on the floor, tightening the belt on the machine, replacing a broken tool, placing oil on a tight screw in a jig, etc.

**Number of Cycles to Be Timed.** The number of cycles to be timed will depend upon the nature of the work but should be sufficient to give a true sample. The following are some of the factors that affect this problem: the length of the cycle, the number of elements in the cycle, possible variation in the length of the cycle, consistency of operator, and the relation of the machine time to the handling time. A well-trained operator working in a consistent and uniform manner will enable the observer to make a satisfactory study with fewer observations than will one who is erratic. Also, when an operation consists largely of machine time fewer observations are ordinarily required than when it is entirely controlled by the operator.

As the time study man records his data he is also evaluating the operator's speed in relation to his opinion of standard speed for such an operation. The observer wants enough stop-watch readings for each element to give him a representative sample against which to apply his speed rating. Later a specific time value will be selected from the data and the rating factor will be applied to this "selected time" or "representative time" to obtain the normal time for the element.

**Rating.** As the observer makes the study he will also determine the performance level, or the rate of speed at which the operator is working. There are a number of different "systems" or methods of arriving at this rating factor although they all depend upon the judgment of the time study man. One of the most common methods is for the analyst to determine a rating factor for the operation as a whole. At the beginning and at the end, and perhaps at intervals throughout the study, the observer concentrates on making ratings of the speed of the operator. It is his object to determine the average level of performance at which the operator was working while the study was being made. Such



a rating is recorded on the observation sheet in the form of a rating factor. (See Fig. 238.)

Another method is for the analyst to determine a rating factor for each element of the operation.<sup>1</sup> This is the plan most widely used today. A still more refined rating plan requires the analyst to rate each element when it is timed, recording the rating for the element on the observation sheet when the stop-watch reading is recorded. Using this method there would be a rating recorded for each stop-watch reading.<sup>2</sup> Although this method is sound it is very difficult for the time study man to rate each stop-watch reading unless the elements are fairly long.

The use of the rating factor will be explained more fully in the next chapter.

**Selecting the Operator to Be Timed.** If more than one person is performing the same operation, the time study man may time one or more of the operators. If all the operators are using exactly the same method, that is, the one prescribed for the job, and if there is a difference in the tempo at which the operators work, it is customary to time the operator working at nearest to normal pace. Since a rating factor is used to evaluate the operator's speed, it theoretically makes no difference whether the slowest or fastest operator is timed. However, it is admittedly more difficult to rate correctly the performance of a very slow operator. It is not desirable to time a beginner because his method is seldom the same as it will be when he has attained greater proficiency through experience on the job. (See Chapter 29.)

The fact that it is important to maintain the good will and cooperation of the employee in motion and time study work should not be overlooked. For psychological reasons it is often better to time an average operator rather than the fastest one. Workers, not fully understanding the process of rating operator performance, are likely to feel that time standards will be set directly on the output of the person timed. If that person is the best one on the job, they may think that the standard time will be so low that it will be very difficult or impossible for the average operator to meet it.

Since full micromotion studies are seldom used in industry for improving methods, the improvement of the job will, in most cases, tie

<sup>1</sup> A recent survey of 744 time study men showed that 34 per cent rated the overall study, 53 per cent rated each element, and 13 per cent rated each stop watch reading.

<sup>2</sup> R. E. Green, "Leveling the Time Study," *Proceedings 1939 Conference*, Industrial Management Society, Chicago, Illinois.



in with the stop-watch time study so that the same operator will serve as the subject for the entire procedure. Frequently there is but a single person on the job; consequently, there is no choice of operator.

**Steps in Making Stop-Watch Time Study Observations:**

1. Discuss the operation to be timed with the foreman of the department.
2. Make certain that the operator has been informed that a time study is to be made.
3. Secure the cooperation of the operator. Explain to him what you are going to do.
4. Make certain that the operation is ready for time study.
5. Obtain all necessary information and record it on the observation sheet.
6. Make a sketch of the piece and of the work place.
7. Divide the operation into its elements and list these on the observation sheet. If necessary describe the method more fully on a separate sheet, listing the beginning and ending points for each element.
8. Record the time of day as the study is begun.
9. Start the decimal stop watch at the beginning of the first element of the cycle. Read and record the time for each element of the cycle.
10. When the study is completed and when the stop watch is read at the end of the last element, read and record the time of day on the sheet.
11. Rate the operator and record these ratings on the observation sheet.
12. Sign and date the study.



## CHAPTER 21

### STOP-WATCH TIME STUDY—DETERMINING THE RATING FACTOR

After the time study has been taken the next step is to subtract successive watch readings in order to get the time for each element. It is advisable to record these subtracted times in ink to make them stand out from the rest of the data and also to insure permanence.

**Selecting Time Values.** As the study on page 372 shows, there are forty-five time values for each of the four elements. It now becomes necessary to select from these data a time value for each of these four elements that will be representative.

Occasionally there may be an abnormally high or low time value due to an error in reading the stop watch; such readings should not be considered in selecting the time value for the elements. However, the fact that there is considerable variation in successive times for certain elements does not mean that all high and low elements should be thrown out. In many cases there are good reasons for such data. An occasional hard casting may require longer drilling time, or a piece with a fin or a burr may take longer to place in the jig. If such time values are typical or representative of what may be expected on the job, they should not be eliminated from the study even though they happen to be abnormal. It is good policy not to eliminate any readings unless there is a definite reason for doing so.

Many organizations use the arithmetic *average* of the stop-watch readings in determining the representative time for the element. Since this is the most common method of handling data and since it is easy to explain to the worker, it is gaining in favor among time study men.

The *model method*, also widely used, consists of taking the time that recurs most frequently for the element. High and low time values will have less effect upon the selected time by this method than by the average method. The selected time values in the time study shown on page 345 were determined by the model method. Some time study men do not use either of the methods but use judgment in arriving at a time value that seems to them to be representative.



It should be remembered that the observer will apply his rating factor to the selected time for the element so that as careful consideration should be given to determining the selected time as is given to the matter of determining the rating factor.

After the time value for each element is selected, the next step in establishing the time standard is to determine and apply the rating factor.

### DETERMINING THE RATING FACTOR

Perhaps the most important and the most difficult part of stop-watch time study is to evaluate the speed<sup>1</sup> or the tempo at which the person is working while the study is being made. The time study man must judge the operator's speed while he is making the time study. This is called rating.

**Definition of Rating.** Rating is that process during which the time study man compares the performance (speed or tempo) of the operator under observation with the observer's own concept of normal performance.<sup>2</sup> Later this rating factor will be applied to the time value to obtain the normal time for the job.

Rating is a matter of judgment on the part of the time study man, and unfortunately there is no way to establish a time standard for an operation without having the judgment of the time study man enter into the process.

We all know that there is a wide difference in the speed at which different people naturally work. For example, some people walk at a slow pace while others walk at a fast pace. The time required for a person to walk a given distance will, of course, vary directly with his walking speed. Speed or tempo can be rated. If walking at a speed of 3 miles per hour is considered normal performance or 100 per cent, we have a definite standard or base to be used in rating the task of walking. Then walking at 2 miles per hour would equal  $66\frac{2}{3}$  per cent of normal, and walking at 4 miles per hour would equal  $133\frac{1}{3}$  per cent. We are measuring accomplishment. If the task is to go from one place to another, and if walking 3 miles per hour is normal or 100 per cent, then without question we can use a percentage rating factor with precision in measuring performance.

<sup>1</sup> The terms speed, effort, tempo, and pace all refer to the rate of speed of the operator's motions. "Speed" and "effort" are terms commonly used by time study men, and the term "tempo" is gaining in favor. In this volume these terms will be used synonymously and they will *all have but a single meaning*, and that is "speed of movement."

<sup>2</sup> S.A.M. Committee on Rating of Time Studies, *Advanced Management*, Vol. 6, No. 3, p. 110, July-September, 1941.



**Rating Factor.** An index number or rating factor is used to indicate the level of performance. It may be expressed in percentage, in points per hour, or in other units. Here we shall use the percentage system with normal performance equal to 100 per cent.<sup>3</sup> Therefore, walking 3 miles per hour equals 100 per cent.

**The Range of Human Capacities.** From our own observations and experience we know that there are wide differences in capacities and abilities of individuals in every activity of life. We have seen champion athletes run the mile in 4 minutes and 1.4 seconds, the 10,000 meter race in 29 minutes and 35.4 seconds, and we have heard of such physical feats as one man's lifting 1384 pounds unaided.<sup>4</sup> These, however, are rare exceptions. Wechsler shows that the range of most physical and mental activities vary as 2 to 1, if the rare exceptions are not considered. That is, the best has roughly twice the capacity of the poorest.

In the factory this means that if a large group of people did exactly the same manual task using the same method, the fastest operator would produce approximately twice the output in a given time as the slowest operator. For example, Table XXI shows the average performance for one day of 121 girls operating semi-automatic lathes, the work being identical for all operators.<sup>5</sup> All were experienced operators. They worked under the point system of wage payment and they were

<sup>3</sup> An investigation of time study practice among 80 companies showed that 55 per cent of the companies use the percentage system, 25 per cent use the point system, 13 per cent use the "Westinghouse" system, and 10 per cent use other systems. The reason the percentage totals more than 100 per cent is because a few of the companies use more than one system. "Work Measurement Manual," by Ralph M. Barnes, published by the William C. Brown Co., Dubuque, Iowa, 3rd ed., p. 197, 1947.

<sup>4</sup> David Wechsler, "The Range of Human Capacities," p. 73, Williams & Wilkins, Baltimore, Md., 1935.

<sup>5</sup> The 121 operators employed on this work were part of a large, well-managed organization that had an excellent reputation over a long period of years. This particular job paid a guaranteed hourly base rate equal to that in the community, and the operators also had an opportunity to earn a bonus. Time standards were carefully and accurately set by stop-watch time study, and they were guaranteed against change. At the time the production record shown in Table XXI was taken, this operation had been in existence many years and the time standard had also been in effect for a long time. The operators working on this job had been selected and trained with considerable care, and they seemed to be convinced that there was no "top on earnings." That is, there was no evidence that the operators were pegging production because of fear that the rate on the job would be cut if an operator earned "too much." Therefore, the output of these 121 operators presents a cross section of performance that might be expected of a group of people employed on a job for which they were reasonably well fitted.



TABLE XXI

DIFFERENCE IN THE PERFORMANCE OF OPERATORS WORKING ON SEMI-AUTOMATIC LATHES

Average Performance of Operators for Friday, Dec. 11, 1936				
Number of Operators	Average Output in Pieces Per Hour for the Day	Distribution		
		No.	Per Cent	Range
1	104	1	1	100 to 109
2	98	5	4	90 to 99
1	91			
2	90			
2	89	25	21	80 to 89
2	87			
1	86			
2	85			
6	84			
2	83			
1	82			
1	81			
8	80			
4	79	40	33	70 to 79
1	78			
3	77			
4	76			
4	75			
1	74			
2	73			
4	72			
3	71			
14	70			
3	69	45	37	60 to 69
2	68			
3	67			
4	66			
3	64			
6	63			
4	62			
6	61			
14	60			
1	58	5	4	50 to 59
1	55			
1	54			
1	52			
1	51			
Total 121	Average 72	121	100	



TABLE XXII

PERFORMANCE OF PEOPLE PARTICIPATING IN AN EXPERIMENT CONSISTING OF PLACING 32 WOOD BLOCKS  $\frac{3}{8}$  INCH BY  $\frac{3}{8}$  INCH BY 2 INCHES (PRE-POSITIONED IN 4 ROWS ON WORK TABLE) IN A 2-INCH BY 4-INCH HOLE,  $4\frac{1}{2}$  INCHES FROM THE EDGE OF THE TABLE

Number of People	Time for Cycle in Minutes	Distribution	
		Number in Interval	Per Cent in Interval
1 5 4 20	0.28 0.30 0.31 0.32	30	6
20 27 33 33 17 20	0.33 0.34 0.35 0.36 0.365 0.37	150	30
16 31 5 35 47 24 25 16	0.375 0.38 0.385 0.39 0.40 0.41 0.42 0.425	199	40
13 11 18 27 10 15 11 4	0.43 0.435 0.44 0.45 0.46 0.47 0.48 0.49	109	22
1 2 2 6 1	0.495 0.50 0.52 0.54 0.60	12	2
Total 500	Average 0.395	500	100



paid a premium for all work produced above 60 pieces per hour, this being the normal performance level established by time study. As the table shows, the poorest operator produced 51 pieces per hour and the best operator produced 104 pieces per hour, or a ratio of 1 to 2.04.

T. R. Turnbull recently conducted an experiment in his plant by having 500 employees toss 32 blocks  $\frac{3}{8}$  inch by  $\frac{3}{8}$  inch by 2 inches (pre-positioned in 4 rows on a work table) into a 2-inch by 4-inch hole  $4\frac{1}{2}$  inches from the edge of the table. The exact method of doing the task was first explained to each "operator." The operator then watched the person ahead of him perform the task, and he was asked to toss

Range  
Average Hourly  
Output in Pieces

Number

50 to 59		5
60 to 69		45
70 to 79		40
80 to 89		25
90 to 99		5
100 to 109		1

FIG. 241. Tally showing number of operators in each range. Average output in pieces per hour of 121 girls working on semi-automatic lathes.

the 32 blocks into the hole as fast as he could. An observer recorded the time taken to perform the operation.

As Table XXII shows, the slowest operator took 0.60 minute (100 cycles per hour) whereas the fastest operator took only 0.28 minute (214 cycles per hour), or a ratio of 1 to 2.14.

This range of 1 to 2 would be expected only if we considered a large number of working people just as they would be found in the factory. In

any large group it is expected that an occasional misfit or an occasional star performer might fall outside the range.

**Frequency Distribution.** With the range of working speeds or operator tempo now established, we are interested in knowing what the distribution would be for a group of factory workers all doing the same job.

Figure 241 shows one way to arrange the average hourly output data for the 121 semi-automatic lathe operators. Those operators who averaged between 50 and 59 pieces per hour for this particular day were tallied in the top horizontal line. There were five people in this group. Those who averaged between 60 and 69 pieces per hour were tallied in the second line. There were 45 people in this group. In a similar manner the operators in each of the six ranges from the slowest to the fastest were tallied, the total being 121 people. Such a graphical tally is called a frequency distribution.

Figure 242 presents a more convenient way to show the frequency distribution. The total range (on the X-axis) is the interval between the lowest hourly production (51) and the highest hourly production (104). The production records were kept to the nearest whole unit



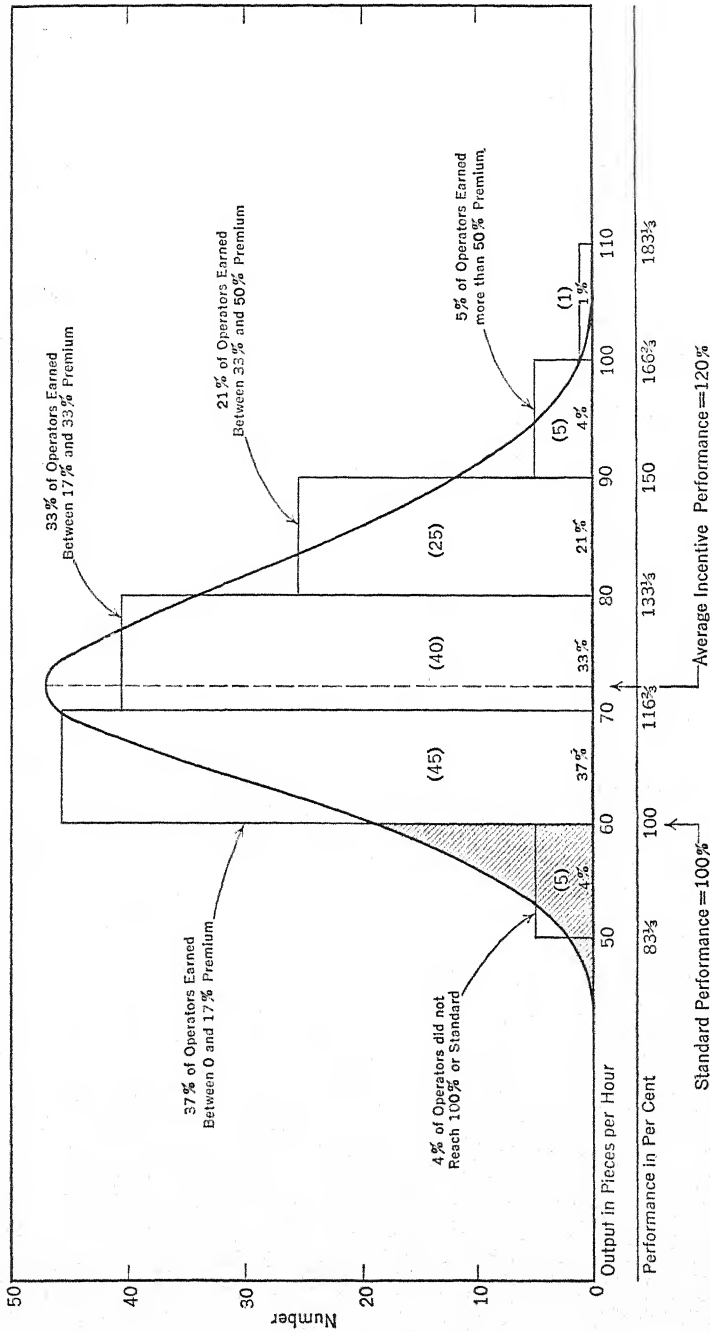


Fig. 242. Curve showing frequency distribution of output in pieces per hour of 121 operators working on semi-automatic lathes. Data taken from Table XXI.



completed each day. The range on the X-axis is divided into six convenient intervals. The smooth curve shown in Fig. 242 is called a frequency distribution curve.

Figure 243 shows the frequency distribution curve for the 500 people who performed the block-tossing operation.

**Establishing a Standard as the Basis for Rating.** The data obtained by a stop-watch time study show the actual time taken by the operator to perform a series of consecutive elements of work. It tells nothing of the pace at which the operator worked while the study was being made. The operator might have been working at a level similar to that of the operator at the top of the column in Table XXI or he might have been working at a level similar to that of the operator at the bottom of the column. It is necessary to consider the operator's speed in order that a standard may be determined that will permit an operator, working at a normal pace, to do the task in the time set for the job.

The need for rating has been pointed out, and the way the rating factor is used has been indicated. It is obvious, however, that some bench mark or some standard of comparison is required if rating is to be used as a measuring device. We must define our normal or standard. To say that normal speed is that speed expected of a qualified person working without incentive, or at a day-work pace, using a standardized method, does not define the term adequately. In fact, there seems to be no written definition that is entirely satisfactory. However, normal speed or normal rate of movement can be demonstrated; motion pictures can be made of typical factory jobs with the operator working at a normal tempo or at a known level above or below normal. Almost any person with average intelligence can be taught to rate operator tempo in terms of the "standard."

Walking on the level at 3 miles per hour<sup>6</sup> is frequently used to represent normal tempo. A person dealing a deck of cards into four equal piles in 0.50 minute is often considered to be exhibiting normal pace.<sup>7</sup> Filling a standard pin board with thirty pins using the two-

<sup>6</sup> Ralph Presgrave, "Dynamics of Time Study," 2nd ed., p. 154, McGraw-Hill Book Co., Inc., New York, 1945.

<sup>7</sup> A standard deck of 52 cards is dealt in the following way by a person seated at a table: The deck is held in the left hand, and the top card is positioned with the thumb and index finger of the left hand. The right hand grasps the positioned card, carries and tosses it onto the table. The four piles of cards are arranged on the four corners of a one-foot square. The only requirement is that the cards shall all be face down and that each of the four piles shall be separate from the others.



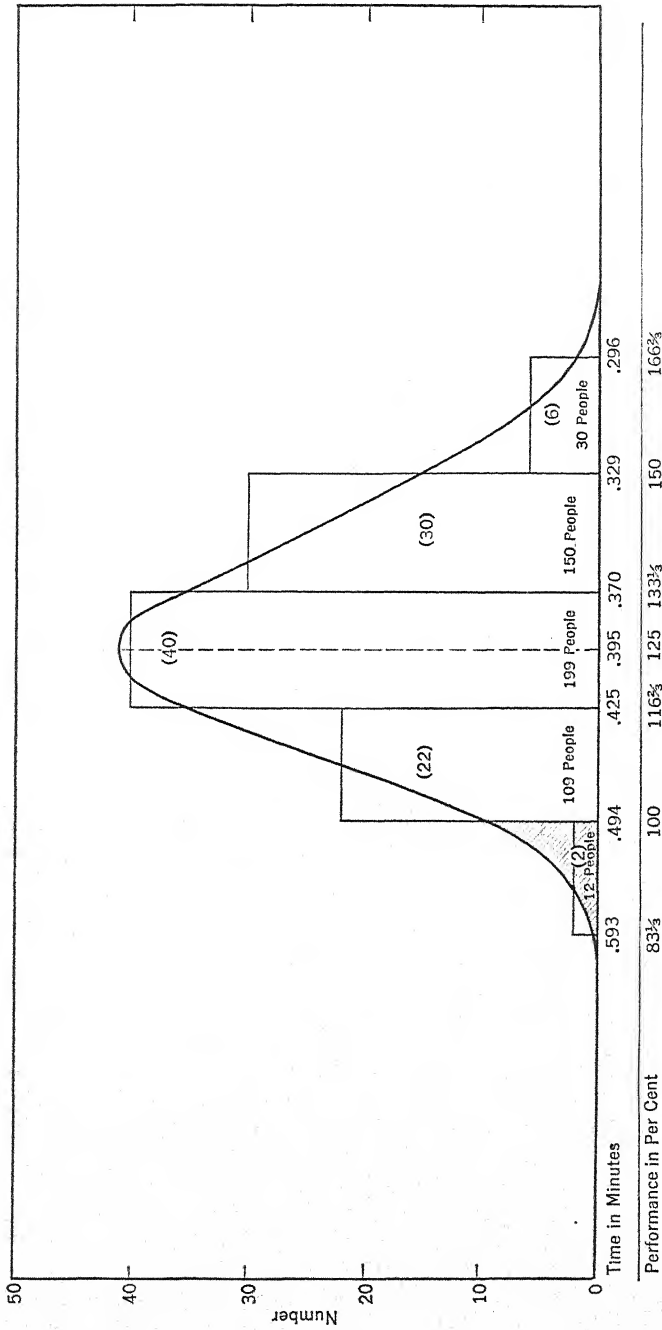


FIG. 243. Curve showing frequency distribution of time taken by 500 people to perform block-tossing operation. Data taken from Table XXII.



handed method in 0.41 minute is also said to represent normal speed.<sup>8</sup>

The General Motors Corporation has made a set of eleven films, each film containing a different sequence of body and arm motions commonly found in factory work. The operator in each of these eleven films is shown working at ten different speeds with a range from 75 per cent to 150 per cent, with 100 per cent as the normal speed. This set of films is used in connection with time study training programs for time study men and to acquaint supervisors and foremen with time study technique.

The Caterpillar Tractor Company has developed a set of performance rating films of many different operations in their plants, as a part of an extensive motion and time study research program. Other companies have established standards of their own or are in the process of establishing such standards.<sup>9</sup>

Some companies have made community time study surveys so that each participating company will know the position of its performance standard with relation to the average for the community.<sup>10</sup>

**The Relation of "Normal Pace" to "Average Incentive Pace."** Since most time standards are used as the basis for some wage-incentive plan, we are interested in the relationship between normal pace and the average pace expected of those on incentive. The average incentive earnings in this country fall between 15 per cent and 35 per cent, with the average around 25 per cent.<sup>11</sup>

The following explanation is presented to show how the relationship between normal pace and average incentive pace may be established in a plant. This illustration also serves to emphasize the point that the performance of the great majority of workers on incentive should be fairly close to the average for the group. If the average incentive pace is 125 per cent, it is expected that the average hourly output of two-thirds of all workers would fall in a range extending from 15 per cent below this point to 15 per cent above this point. Only 3 or 4

<sup>8</sup> For specifications of the pin board and for a description of the method, see pages 107 and 108. Also see "Work Measurement Manual," by Ralph M. Barnes, 3rd ed., p. 63; or "Work Methods Manual," by Ralph M. Barnes, pp. 62 and 89.

<sup>9</sup> The author has ten silent films and three sound films showing 25 different operators working at a total of 80 different speeds. The silent films have been rated by 5000 people from over 350 different companies in the United States and Canada during the past two years as a part of the Work Measurement Project. A standard rating factor has been established for each operation shown in these films.

<sup>10</sup> See "Work Measurement Manual," by Ralph M. Barnes, 3rd ed., pp. 145-155.

<sup>11</sup> *Ibid.*, p. 148.



per cent of the group would be expected to exceed the 150 per cent performance level and only rarely would an operator exceed the 160 to 165 per cent level.

Reference will be made to the normal distribution curve (see Fig. 244) for data to support the above statements. There is considerable evidence to show that if the working speed of each member of a large group of people, such as would be found in a factory, were arranged along the base line according to magnitude in per cent of normal, and if the vertical scale indicated frequency, the shape of the curve would fit fairly closely the normal bell curve.

This assumption having been made, a normal distribution curve can be drawn (see Fig. 244) with five intervals covering a total speed range of 200 per cent. The pace of the slowest operator is one-half that of the fastest operator, which gives a ratio of 1 to 2. The next step is to establish the point on the curve that will represent normal speed.<sup>12</sup> If we assume that this group of people is already working on incentive, and if their average incentive pace is 25 per cent above normal, then point *A* in Fig. 244 can be called 125 per cent. This point would represent the average for the group. If the length of the line *B-C* represents a speed range from  $83\frac{1}{3}$  to  $166\frac{2}{3}$  per cent, point *D* represents 100 per cent or normal speed. In a similar manner point *B* represents  $83\frac{1}{3}$  per cent, point *E* represents  $116\frac{2}{3}$  per cent, *F* represents  $133\frac{1}{3}$  per cent, *G* represents 150 per cent, and *C* represents  $166\frac{2}{3}$  per cent. Thus there is a range between  $83\frac{1}{3}$  per cent and  $166\frac{2}{3}$  per cent of 1 to 2. The number in each of the vertical bars represents the number of people per hundred which would fall in each of the five intervals.<sup>13</sup>

It is of course not expected that any group of workers would exactly fit the normal curve, although an examination of Fig. 242 on page 357 will show that the output of this group of 121 operators tends to fit the normal curve. It should be noted that the standard established by time study was 60 pieces per hour, that is, 60 pieces per hour was equal to normal performance or 100 per cent. The average output for the entire group was 72 pieces per hour, which is 20 per cent above the standard. Thus 120 per cent would be the average incentive performance for this group of workers for this particular day. There were

<sup>12</sup> This method of determining the relationship between normal performance and average incentive performance, suggested by Ralph Presgrave, seems to be the most logical of any yet presented. See "Dynamics of Time Study," by Ralph Presgrave, Chapter 10, 2nd ed., McGraw-Hill Book Co., Inc., New York, 1945.

<sup>13</sup> For the formula for the normal distribution curve see any book on statistics.



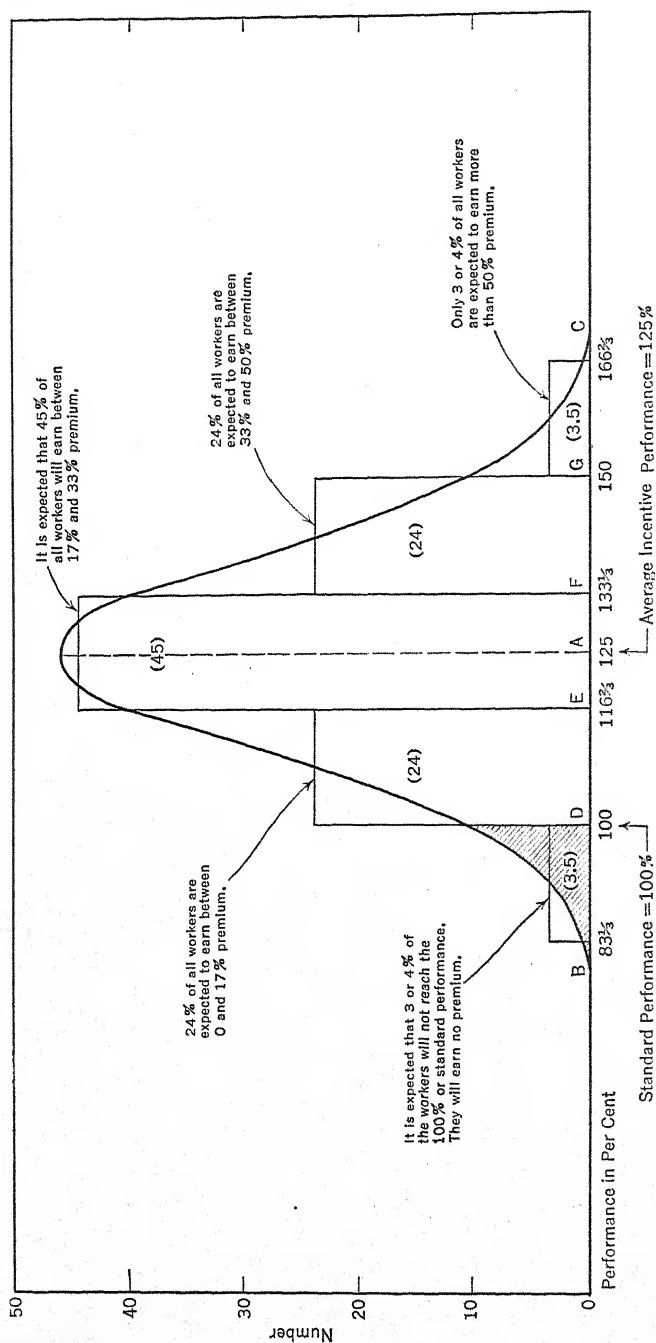


Fig. 244. Chart showing the number of workers in each class interval through entire performance range as determined from the normal distribution curve. Normal performance equals 100 per cent. Average incentive performance equals 125 per cent. Ratio of slowest worker (83 1/3 per cent) to fastest worker (166 2/3 per cent) is 1 to 2. A 100 per cent premium plan of wage payment is used. It is assumed that a premium is paid for all production above standard. That is, for each one per cent increase in production above standard, the worker is paid one per cent additional wage above his hourly base rate. The base rate is the guaranteed wage paid to all workers whether they reach 100 per cent performance or not. This hourly base rate is established by job evaluation.



five operators who worked at such a slow pace that they did not reach the 100 per cent or normal performance level. Incidentally, these slow

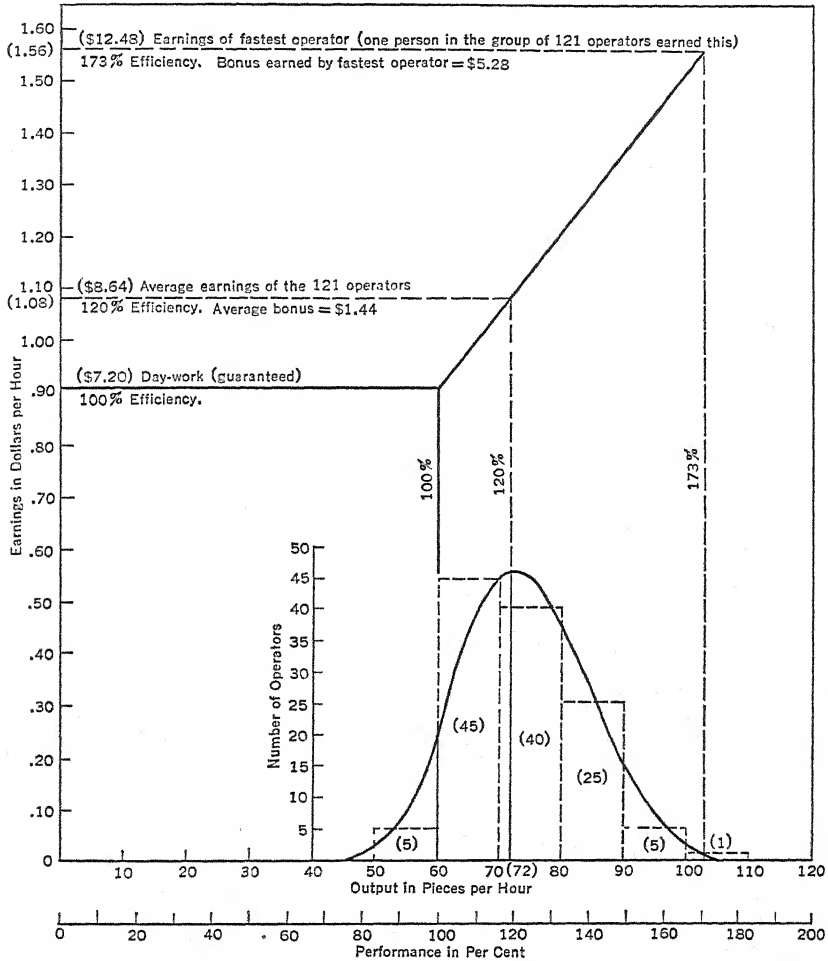


FIG. 245. Distribution and earnings curve for 121 semi-automatic lathe operators. The average output is 72 pieces per hour, and average earnings for the group are 20 per cent above the guaranteed hourly rate.

operators were paid their guaranteed day rate, even though they did not earn it. The very fastest operator turned out 104 pieces per hour, which was 73 per cent above normal. In other words, this operator worked at a pace equal to 173 per cent. Figure 245 shows the distribution and earnings curve for 121 semi-automatic lathe operators.



The frequency distribution curve (see Fig. 243) for the block-tossing operation also closely resembles the normal distribution curve.

**Establishing a Company Standard.** After the basic reasoning back of rating is fully understood, each company should establish a standard for its own use. Agreement should be reached as to what the normal or standard tempo, or performance level, should be in the plant. The first step would be to establish a standard for walking, card dealing, and other similar operations used generally throughout the country. Incidentally, the standards given on page 358 are widely used.

Then some simple operations from the plant which can be performed by anyone should be selected for demonstration. The method should be standardized, and the time for each job, with the operator working at normal pace, should be established. Motion pictures at 1000 frames per minute should be made of typical factory jobs, and the operator's tempo in per cent of normal should be established for each of them. Thus a library of standard rating films can be built up over a period of time for use as a bench mark for rating in the plant. Not only can time study men be taught to rate, but foremen, supervisors, and operators themselves can also do this; and they are doing it in many plants today.

**Systems of Rating.** There are several systems of rating in general use, and undoubtedly a competent and well-trained time study man can obtain satisfactory results using any one of them. A recent survey shows that the percentage system has greatest use and the point system comes next.

A study of the four different rating scales shown in Fig. 246 may help to show the difference between these systems. Just as we can read temperature on both Fahrenheit and centigrade thermometers, although there is a difference in their scale, so we can rate operator speed whether he uses percentage, points, or some other unit of measure. Since the percentage system is the plan having widest use in this country, it will be used in most of the illustrations in this volume.

*Scale A—100 Per Cent Equals Normal Performance.* Normal performance (that is, normal speed, tempo, or pace) equals 100 per cent on rating Scale A (see Fig. 246). When this scale is used it is expected that the average incentive pace will fall in the range of 115 per cent to 135 per cent, and the average for the entire group will be around 125 per cent. This means that those operators who turn out between 15 and 35 per cent per day more than normal will earn 15 to 35 per cent extra pay for this extra performance. It is also expected that an occasional person, perhaps one in a thousand, would work at a pace twice



as fast as normal. His effort rating would thus be 200 per cent, and consequently he would earn twice the hourly base rate.

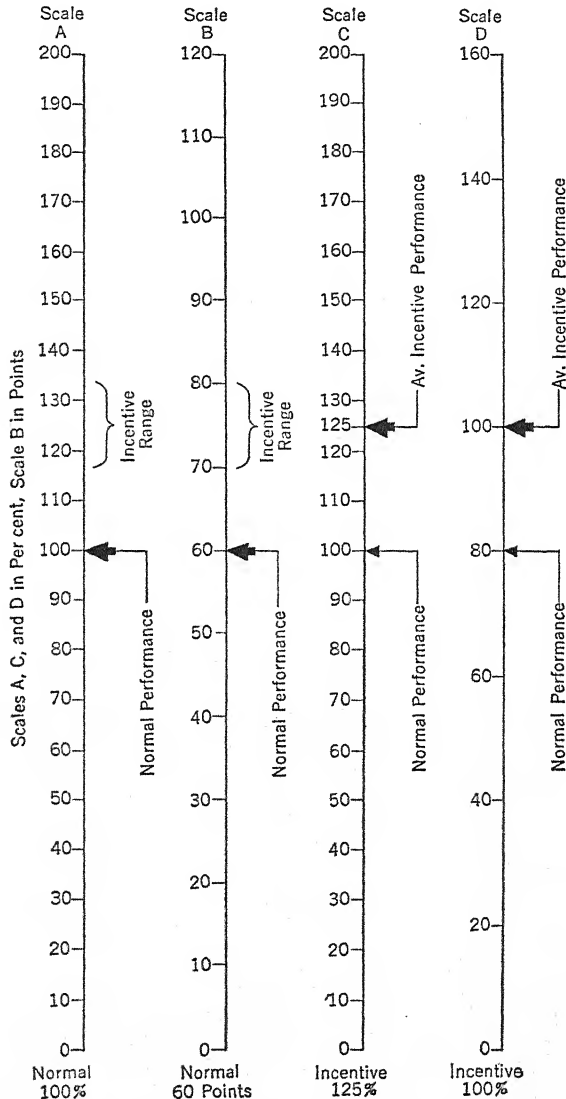


FIG. 246. Four different rating scales.

*Scale B—60 Points Equals Normal Performance.* Scale B illustrates the point system with 60 points equal to normal performance and with the average incentive pace around 70 to 80 points. The maxi-



imum expected performance is around 100 to 120 points. This scale is similar to Scale A with 60 points equal to 100 per cent performance rating.

*Scale C—125 Per Cent Equals Incentive Performance.* There are some time study men who use the "average incentive pace" as their bench mark. One company, for example, has adopted 125 per cent as the point at which they would like to have the average output fall. Therefore, they try to determine this point and set their "incentive time standard" at this point, and then add 25 per cent to their hourly base rate in computing the amount of earnings that a person should receive at this point. For example, instead of stating that the time standard is 1.00 minute per piece and the base rate is, say, 90 cents per hour, giving a piece rate of  $1\frac{1}{2}$  cents per piece, they would state that the expected incentive output is 75 pieces per hour and that, when the operator reaches this point, he would be paid  $\$1.12\frac{1}{2}$  per hour (which is, of course, at the rate of  $1\frac{1}{2}$  cents per piece). Although this plan is perhaps as sound as any other, some people think it is not so easy to explain to the operators and that it has no advantages over a plan using Scale A.

*Scale D—100 Per Cent Equals Incentive Performance.* A few organizations use a scale having 100 per cent equal to "average incentive pace," and this point is usually set 25 per cent above normal performance. Therefore, 80 per cent equals normal performance on this scale.

**Speed and Method as They Affect Output.** To summarize, there are two main factors that affect the number of units of work that a person on manual operations can produce in a given time. They are:

1. Speed of muscular movements.
2. Method of doing the task.

Speed or tempo, which refers to the rate of physical activity of the worker, can be measured by the rating factor, as has already been described. Method is ordinarily defined as the specified motion pattern required to perform a given operation. From the practical point of view, the method for a particular operation must be one which can be maintained in the shop, day in and day out, and it must be one that the worker can be trained to follow. With this definition of method it is obvious that different individuals working on a job will, with practice, develop some refinements. Some would say that they have become more highly skilled. However, if a careful analysis were made of the operation it generally would be found that a skilled per-



son uses a different method from the one he used when he was less skilled on the job. Evidence to support this point is presented in Chapter 29.

Since there is neither a bench mark nor a unit for measuring differences in method, the only satisfactory way to handle this factor is to standardize the method and establish a standard time for this specified method. Thus the time standard would not apply if a method other than the standard were used.

Although some variation in method is expected in the average factory, if care is used in developing the proper method of doing the job and if the operators are trained to do the work in the specified manner before the time study is made, the problem of variations in output due to variations in method can be minimized.

**Applying the Rating Factor.** The rating factor is applied to the selected time to give the normal time. Assume that in a particular operation of assembling an electric switch the operator gave a consistent performance throughout the entire cycle and throughout the entire study and that the total selected time was 0.80 minute. With a rating factor for the study of 110 per cent, the normal time would be as follows:

$$\text{Normal Time} = (\text{Selected Time}) \times \frac{(\text{Rating in Per Cent})}{100}$$

$$\text{Normal Time} = 0.80 \times \frac{110}{100} = 0.88 \text{ minute}$$

This value of 0.88 represents the time that an operator working at a normal pace would need to complete one cycle of the operation. This value is not the standard time for the job since allowances must be added to the normal time to give the standard time. The determination and the application of allowances will be explained in the next chapter.



## CHAPTER 22

### STOP-WATCH TIME STUDY—DETERMINING ALLOWANCES AND TIME STANDARD

The *normal time* for an operation does not contain any allowances. It is merely the time that a qualified operator would need to perform the job if he worked at a normal tempo. However, it is not expected that a person will work all day without some interruptions. The operator may take time out for his personal needs, for rest, and for reasons beyond his control. Allowances for such interruptions to production may be classified as follows: (1) personal allowance, (2) fatigue allowance, or (3) delay allowance.

The standard time must include time for all the elements in the operation and, in addition, it must contain time for all necessary allowances. Standard time is equal to the normal time plus the allowances. Allowances are not a part of the rating factor, and best results are obtained if they are applied separately.

**Personal Allowance.** Personal allowance will be considered first because every worker must be allowed time for his personal needs. The amount of this allowance can be determined by making all-day time studies of various classes of work. For light work, where the operator works 8 hours per day without organized rest periods, 2 to 5 per cent (10 to 24 minutes) per day is all that the average worker will use for personal time.

Although the amount of personal time required will vary with the individual rather than with the kind of work, it is a fact that employees need more personal time when the work is heavy and done under unfavorable conditions, particularly in hot humid atmosphere. Under such conditions studies might possibly show that more than 5 per cent allowance should be made for personal time.

**Fatigue Allowance.** In the modern well-managed plant in this country so many steps have been taken to eliminate fatigue that it is not of as great concern as formerly. In fact, fatigue is of such little consequence in some kinds of work that no allowance is required at all. There are many reasons for this. The length of the working day and the length of the working week have been shortened; machinery, mechanical handling equipment, tools, and fixtures have been improved so that the day's work is more easily done and the employee works in



greater physical comfort than formerly. Accident hazards have also been reduced so that the fear of physical injury is of less importance.

Professor A. G. Anderson of the University of Illinois spent a year studying the effect of fatigue upon the worker in a large midwestern factory. He states:

"The general and final conclusion of this study of human fatigue is, then, to the effect that industrial operations as carried on in a modern, progressively managed manufacturing plant do not subject the workers to undue fatigue, either physical or mental, and that fatigue is not a factor tending to limit production."<sup>1</sup>

Of course, there are some kinds of work that still involve heavy physical exertion and are performed under adverse conditions of heat, humidity, dust, and accident hazards and, therefore, require rest for the operator. Fatigue results from a large number of causes, some of which are mental as well as physical.

There is at the present time no satisfactory way of measuring fatigue except in terms of reduced output resulting from work, and then we cannot say with certainty that the reduction in output results from fatigue. The fact that a worker turns out fewer units during the last hour of the day may, of course, be due to the fact that he is tired. It may also be due to other factors.

We know from experience that a person needs time for rest when his work is arduous. The problem of determining the amount of time to be allowed for rest is very complex. Time needed for rest varies with the individual, with the length of the interval in the cycle during which the person is under load, with the conditions under which the work is done, and with many other factors. Some companies have from long experience arrived at fatigue allowances which seem to be satisfactory. (See Fig. 247.) A few organizations having heavy physical work, such as stacking heavy boxes in warehouses or in freight cars, have tried out various combinations of periods of rest and work until they have arrived at satisfactory allowances.

Organized rest periods during which time all employees in a department are not permitted to work provide one of the best solutions to the problem. Of course the optimum length and number of rest periods must be determined. Perhaps the most common plan is to provide one rest period during the middle of the morning and one during the middle of the afternoon. The length of these periods ordinarily vary from 5 to 15 minutes each.

If no wage-incentive plan is used some companies pay for the rest periods at the employee's regular hourly base rate. If a wage-incentive

<sup>1</sup> A. G. Anderson, "A Study of Human Fatigue in Industry," an abstract of a thesis, p. 22, University of Illinois.



FATIGUE AND PERSONAL ALLOWANCE TABLE	
30	Handle 70-pound containers from skid waist-high to shoulder-high stack.
29	
28	Handle 60-pound containers from skid waist-high to shoulder-high stack. Pull loaded 4-wheel truck under normal conditions. (Gross weight, 2300 pounds. Wheel diameter, 11 inches.)
27	
26	Up-end rosin barrel weighing 500 pounds gross. (Two men.) Shovel salt from open-end box truck to kettle 40 inches high. (Shovel weight, 6 pounds; salt weight, 20 pounds.)
25	Walking on level carrying 75 pounds on shoulder. Push loaded wheelbarrow. (Weight of material, 350 pounds.)
24	Push loaded 4-wheel truck. (Gross weight, 2000 pounds; wheel diameter, 11 inches.) Handle 65-pound containers from skid waist-high to R.R. car knee high.
23	Handle 40-pound containers from skid waist-high to shoulder-high stack.
22	Handle 65-pound containers from skid waist-high to knee-high stack. Use pick weighing 9 pounds to loosen new salt in R.R. car. Paint smooth ceiling from step-ladder using a 4-inch brush.
21	Handle 50-pound containers from waist-high slide to skid.
20	Pull loaded 4-wheel truck. (Gross weight, 1500 pounds; wheel diameter, 11 inches.)
19	Wet-mop rough concrete floor.
18	Dry-mop rough concrete floor. Saw a yellow pine 2" X 4" across grain.
17	Handle 30-pound containers from waist-high slide to skid. Pull loaded 4-wheel truck. (Gross weight, 1000 pounds; wheel diameter, 11 inches.) Wet-mop wooden floor in good condition.
16	Dry-mop wooden floor in good condition. Scrape dirt from wooden floor in good condition. (Handle of scraper 60 inches long, blade 6½ inches wide.)
15	Walking on level carrying 25 pounds. Sweep rough concrete floor.
14	Handle 20-pound containers from waist-high slide to skid. Dry and polish window with rag, working from inside. Form and stitch fiber containers.
13	Sweep a wooden floor in good condition. Wash window with wet rag or sponge, working from inside.
12	Pull empty 4-wheel truck. (Weight, 400 pounds; wheel diameter, 11 inches.) Operate typewriter.
11	Cut strings on bundles of containers.
10	Walking on level unobstructed.
9	
8	
7	Visual inspection and maintaining register for printed labels.
6	
5	Personal allowance for women. Personal allowance for men.
4	

FIG. 247. Personal and fatigue allowances used by one company having mainly handling and hand-truck operations. The allowances given include personal time.



plan is used and if fatigue allowances have been incorporated in the time standard, employees are not paid for the rest periods as such. The worker merely takes his fatigue allowance during the specified rest period rather than at intervals during the day at his own choosing.

It should be repeated that a fatigue allowance does not need to be made for much light factory work, and organized rest periods during the day provide sufficient rest for another group of factory operations. The amount of heavy work in factories is gradually decreasing because of the greater use of machinery and power-handling equipment; consequently the problem of fatigue allowances becomes one of decreasing importance to the time study man.

**Delay Allowance.** Delays may be avoidable or unavoidable. Those delays that the operator makes intentionally will, of course, not be considered in determining the time standard. Unavoidable delays do occur from time to time, caused by the machine, the operator, or by some outside force.

It is expected that machines and equipment will be kept in good repair. However, when there is a breakdown or when repairs are necessary, the operator is usually taken off the job and such delays do not enter into the time standard. In such cases the operator is usually paid for waiting time at his hourly base rate. Sometimes there are minor adjustments, breakage of tools such as drills and taps, lost time due to occasional variation in material and interruptions by supervisors, and they must be included in the standard. Each unavoidable delay should be considered as a challenge by the analyst and the foreman, and every reasonable effort should be made to eliminate these delays. The kind and amount of delays for a given class of work can best be determined from all-day time studies or delay studies made over a sufficient period of time to give reliable data.

**Applying the Allowances.** Personal allowance is applied as a percentage of the normal time and affects both handling time and machine time alike. For convenience, fatigue allowance is sometimes applied in the same way, although some believe that this allowance should apply only to those elements during which the operator works and not to the machine time during which the machine works. Delays are applied as a percentage of the normal time or, if entirely a machine-delay allowance, then only on the machine elements. If these three allowances are applied uniformly to all elements, they may be added together and applied together, necessitating but a single computation.



STUDY NO. 8765		OBSERVATION SHEET															SHEET 1 OF 1 SHEETS											
ELEMENTS	SPEED/FEED	UPPER LINE: SUBTRACTED TIME										LOWER LINE: READING										MIN. TIME	AV. TIME	SECT. TIME	CYCLE	EFFORT	NORMAL	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15												
1. Fill core box with 3 handfuls of sand. Press sand down each time.		.09	.09	.09	.09	.08	.08	.10	.07	.08	.08	.09	.07	.08	.09	.06	.06	.081	.081	1	115	.093						
2. Press sand down with one trowel stroke. Strike off with one trowel stroke.		.09	.41	.71	1.07	.38	.67	.98	.28	.57	.87	.18	.46	.76	1.05	.32	.06	.059	.059	1	125	.074						
3. Get and place plate on core box, turn over, rap, and remove box.		.15	.46	.79	.13	.43	.72	2.04	.33	.62	.93	.24	.51	.81	.11	.38	.10	.126	.126	1	135	.170						
4. Carry plate with core 4 feet. Dispose on oven truck.		.28	.59	.94	.27	.56	.85	.18	.46	.76	3.06	.36	.65	.93	.24	.51	.02	.032	.032	1	125	.040						
(1)		.61	.95	.25	.53	.83	.12	.41	.71	7.01	.28	.55	.84	.16	.48	.77												
(2)		.05	.05	.05	.05	.06	.06	.06	.06	.05	.06	.06	.07	.06	.05	.05												
(3)		.66	5.00	.30	.58	.89	.18	.47	.77	.06	.34	.61	.91	.22	.53	.82												
(4)		.80	.13	.42	.71	6.01	.31	.60	.89	.17	.12	.13	.13	.14	.13	.13												
(1)		.05	.04	.03	.04	.03	.03	.03	.04	.03	.02	.03	.04	.03	.02	.03												
(2)		.85	.17	.45	.75	.04	.34	.63	.93	.20	.48	.77	.08	.39	.68	.98												
(3)		.07	.07	.08	.08	.07	.08	.07	.08	.09	.08	.08	.09	.08	.08	.09												
(4)		9.05	.34	.64	.93	.21	.50	.78	11.07	.39	.69	.99	.29	.59	.89	.19												
(1)		.05	.06	.05	.06	.06	.07	.06	.07	.06	.07	.06	.07	.06	.06	.08												
(2)		.10	.40	.69	.99	.27	.57	.84	.14	.47	.76	12.05	.35	.66	.95	.27												
(3)		.14	.13	.13	.11	.12	.11	.11	.12	.10	.12	.12	.13	.12	.12	.11												
(4)		.24	.53	.82	10.10	.39	.68	.95	.26	.57	.88	.17	.48	.78	13.07	.38												
		.03	.03	.03	.04	.03	.03	.04	.04	.04	.03	.03	.03	.03	.03	.03												
		.27	.56	.85	.14	.42	.71	.93	.30	.61	.91	.20	.51	.81	.10	.41												
FOREIGN ELEMENTS:		Tally-by elements															TOOLS, GAUGES, PATTERNS, ETC.											
		No. 1	No. 2	No. 3	No. 4																							
		.06- .07- .08- .09- .10- 11- 12- 13- 14- 15- 16- 17- 18- 19- 20- 21- 22- 23- 24- 25- 26- 27- 28- 29- 30- 31- 32- 33- 34- 35- 36- 37- 38- 39- 40- 41- 42- 43- 44- 45- 46- 47- 48- 49- 50- 51- 52- 53- 54- 55- 56- 57- 58- 59- 60- 61- 62- 63- 64- 65- 66- 67- 68- 69- 70- 71- 72- 73- 74- 75- 76- 77- 78- 79- 80- 81- 82- 83- 84- 85- 86- 87- 88- 89- 90- 91- 92- 93- 94- 95- 96- 97- 98- 99- 100- 101- 102- 103- 104- 105- 106- 107- 108- 109- 110- 111- 112- 113- 114- 115- 116- 117- 118- 119- 120- 121- 122- 123- 124- 125- 126- 127- 128- 129- 130- 131- 132- 133- 134- 135- 136- 137- 138- 139- 140- 141- 142- 143- 144- 145- 146- 147- 148- 149- 150- 151- 152- 153- 154- 155- 156- 157- 158- 159- 160- 161- 162- 163- 164- 165- 166- 167- 168- 169- 170- 171- 172- 173- 174- 175- 176- 177- 178- 179- 180- 181- 182- 183- 184- 185- 186- 187- 188- 189- 190- 191- 192- 193- 194- 195- 196- 197- 198- 199- 200- 201- 202- 203- 204- 205- 206- 207- 208- 209- 210- 211- 212- 213- 214- 215- 216- 217- 218- 219- 220- 221- 222- 223- 224- 225- 226- 227- 228- 229- 230- 231- 232- 233- 234- 235- 236- 237- 238- 239- 240- 241- 242- 243- 244- 245- 246- 247- 248- 249- 250- 251- 252- 253- 254- 255- 256- 257- 258- 259- 260- 261- 262- 263- 264- 265- 266- 267- 268- 269- 270- 271- 272- 273- 274- 275- 276- 277- 278- 279- 280- 281- 282- 283- 284- 285- 286- 287- 288- 289- 290- 291- 292- 293- 294- 295- 296- 297- 298- 299- 300- 301- 302- 303- 304- 305- 306- 307- 308- 309- 310- 311- 312- 313- 314- 315- 316- 317- 318- 319- 320- 321- 322- 323- 324- 325- 326- 327- 328- 329- 330- 331- 332- 333- 334- 335- 336- 337- 338- 339- 340- 341- 342- 343- 344- 345- 346- 347- 348- 349- 350- 351- 352- 353- 354- 355- 356- 357- 358- 359- 360- 361- 362- 363- 364- 365- 366- 367- 368- 369- 370- 371- 372- 373- 374- 375- 376- 377- 378- 379- 380- 381- 382- 383- 384- 385- 386- 387- 388- 389- 390- 391- 392- 393- 394- 395- 396- 397- 398- 399- 400- 401- 402- 403- 404- 405- 406- 407- 408- 409- 410- 411- 412- 413- 414- 415- 416- 417- 418- 419- 420- 421- 422- 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1019- 1020- 1021- 1022- 1023- 1024- 1025- 1026- 1027- 1028- 1029- 1030- 1031- 1032- 1033- 1034- 1035- 1036- 1037- 1038- 1039- 1040- 1041- 1042- 1043- 1044- 1045- 1046- 1047- 1048- 1049- 1050- 1051- 1052- 1053- 1054- 1055- 1056- 1057- 1058- 1059- 1060- 1061- 1062- 1063- 1064- 1065- 1066- 1067- 1068- 1069- 1070- 1071- 1072- 1073- 1074- 1075- 1076- 1077- 1078- 1079- 1080- 1081- 1082- 1083- 1084- 1085- 1086- 1087- 1088- 1089- 1090- 1091- 1092- 1093- 1094- 1095- 1096- 1097- 1098- 1099- 1100- 1101- 1102- 1103- 1104- 1105- 1106- 1107- 1108- 1109- 1110- 1111- 1112- 1113- 1114- 1115- 1116- 1117- 1118- 1119- 1120- 1121- 1122- 1123- 1124- 1125- 1126- 1127- 1128- 1129- 1130- 1131- 1132- 1133- 1134- 1135- 1136- 1137- 1138- 1139- 1140- 1141- 1142- 1143- 1144- 1145- 1146- 1147- 1148- 1149- 1150- 1151																										



OPERATION: Make Core for Crank Frame No. 7253															
OP. NO.: C-10-A															
PART NAME: Core for Crank Frame No. 7253															
MACH. NAME: Bench No. 62															
MACH. NO.: —															
OPERATOR'S NAME & NO.: S.P. Martin															
EXPERIENCE ON JOB: Six Months															
FOREMAN: M.L. Roy															
NO. MACHINES OPER'D: — MACH. SPEED — DEPT. NO.: 17															
MATERIAL: Dry core sand, Specification No. A16															
SCALE: One square = 4 inches															
SKETCH OF WORK PLACE															
<table border="1"> <thead> <tr> <th>DATE OF STUDY</th> <th>OBSERVER</th> <th>APPROVED</th> </tr> </thead> <tbody> <tr> <td>1-14-48</td> <td>C.A. Clark</td> <td>J.S.R. 1-16-48</td> </tr> </tbody> </table>										DATE OF STUDY	OBSERVER	APPROVED	1-14-48	C.A. Clark	J.S.R. 1-16-48
DATE OF STUDY	OBSERVER	APPROVED													
1-14-48	C.A. Clark	J.S.R. 1-16-48													

SUMMARY						
NO.	ELEMENTS	NORMAL TIME	PIECES PER CYCLE <sup>2</sup>	OTHER ALLOW.	TOTAL ALLOW.	STD. TIME
1.	Fill core box with 3 handfuls of sand.	.093	12	—	12	.104
2.	Press sand down with one trowel stroke.	.074	15	—	15	.085
3.	Strike off with one trowel stroke.	.170	15	—	15	.195
4.	Get and place plate on core box, turn over, rap, and remove box.	.040	12	—	12	.045
5.	Carry plate with core 4 feet.					
6.	Dismiss on oven truck.					.429
TOTAL STD. TIME PER CYCLE:						
NO. PIECES PER CYCLE: 1						.429
DRAWING OF PART:						Use .43
<p>Core:</p> <p>One half of cylinder <math>1\frac{3}{16}'' \times 7\frac{1}{2}''</math>          Wt. of core before baking = <math>\frac{3}{4}</math> lb.</p>						

Fig. 249. Back of observation sheet—core-making operation.



Although allowances have traditionally been applied as a percentage of the normal time to be added to the normal time to obtain the standard time, there is a trend toward considering allowances in terms of minutes allowed per working day. Thus, instead of referring to personal allowance as 5 per cent, it would be referred to as 24 minutes per 8-hour day ( $480 \times 5\% = 24$ ). If this were the only allowance made, the working time in this case would be 456 minutes per day ( $480 - 24 = 456$ ).

If an allowance of 5 per cent for personal time were made on the assembly operation referred to on page 367, 5 per cent would be added to the normal time for this operation in the following way:

$$\text{Standard Time} = (\text{Normal Time}) + [(\text{Normal Time}) \times (\text{Allowances in Per Cent})]$$

$$\text{Standard Time} = 0.88 + (0.88 \times 0.05) = 0.88 + 0.044 = 0.924 \text{ minute}$$

To summarize:

Selected Time	= 0.80 minute
Rating Factor	= 110 per cent
Personal Allowance	= 5 per cent
Normal Time	= $0.80 \times \frac{110}{100} = 0.88 \text{ minute}$
Standard Time	= $0.88 + (0.88 \times 0.05) = 0.924 \text{ minute}$

Another way to compute this is:

$$\text{Standard Time} = 0.88 \times 1.05 = 0.924 \text{ minute.}$$

Although the method of applying the personal allowance illustrated above is the most common one in use today, it is not absolutely correct. If by a 5 per cent allowance it is understood that 24 minutes per 8-hour day are to be available to the worker for his personal needs, and if the normal time for one assembly of the electric switch is 0.88 minute, then during the 456 minutes available for work ( $480 - 24 = 456$ ), the operator could produce 518 pieces ( $456 \div 0.88 = 518$ ). Since the 8-hour day consists of 480 minutes the standard time per piece would be 0.926 minute ( $480 \div 518 = 0.926$ ). Another way to state this is:

$$\text{Standard Time} = \text{Normal Time} \times \left[ \frac{100}{(100 - \text{Allowance in Per Cent})} \right]$$

$$\text{Standard Time} = 0.88 \times \left[ \frac{100}{(100 - 5)} \right]$$

$$\text{Standard Time} = 0.88 \times \frac{100}{95} = 0.926 \text{ minute}$$



This method of incorporating allowances into the time standard is not only correct, but there is considerable value in stating the total time in minutes per 8-hour day for each type of allowance. To the foreman or operator the statement that 24 minutes per day is allowed for personal time means more than merely to say that 5 per cent has been added to the normal cycle time for personal needs.

**Stop-Watch Time Study of a Core-Making Operation.** The study shown in Fig. 238 on page 345 is a very common type of stop-watch time study used today, although many organizations rate each element separately instead of making an overall rating for the study, and also determine and apply a fatigue and personal allowance factor for each element. Figures 248 and 249 show such a study.

The operation studied was the making of a dry sand core in a wood core box. The core was  $7\frac{1}{2}$  inches long and  $1\frac{3}{16}$  inches in diameter, taking the general shape of half a cylinder.

A full description of the operation is given in the left-hand column below, and the abbreviated description recorded on the observation sheet is given in the right-hand column below. The end points used in reading the watch are also given.

*Condensed Description of the Operation  
As Recorded on the Observation Sheet.  
(The end points for reading the watch are  
also given.)*

*Detail Description of the Operation*

- |  |  |
|--|--|
| <p>1. Walk 4 feet from core-oven truck to bench, pick up core box with both hands, push loose sand on front edge of bench back against pile with edge of core box. Hold core box with left hand and fill core box with three handfuls of sand, pressing sand down in core box each time.</p> | <p>1. Fill core box with 3 handfuls of sand. Press sand down each time. <i>End of element</i> as right hand begins to grasp trowel.</p>                |
| <p>2. Pick up trowel with right hand, press sand down with one stroke of trowel across top of box, strike off (draw edge of trowel across top of box), removing excess sand with edge of trowel. Dispose of trowel on bench at right of core box.</p>  | <p>2. Press sand down with one trowel stroke. Strike off with one trowel stroke. <i>End of element</i> as trowel is dropped on bench (hits bench).</p> |
| <p>3. Get plate and carry from pile on bench 3 feet to left of core box, turn plate upside down, and place on top of core box. Turn plate and core box over. Pick up trowel with right hand and rap core box twice with handle of</p>  | <p>3. Get and place plate on core box, turn over, rap, and remove box. <i>End of element</i> as core box is placed on bench (hits bench).</p>          |







The selected time value for each element is determined by tallying the data as shown on the bottom of the observation sheet. If there is not space on this sheet the tally is made on a plain sheet of paper and attached to the observation sheet. The tally shows that, for Element 1, 0.06 is the minimum time value, 0.08 is the time value that occurs most frequently, and 0.081 is the average. In a similar manner values are determined for the other three elements of the study. The number of times that the element occurs in the study is recorded in the column marked "Occurrence per Cycle."

The normal times are then calculated in the following way:

$$\text{Normal Time} = (\text{Selected Time}) \times \frac{\text{Rating in Per Cent}}{100}$$

For Element 1, the normal time (see Fig. 250) is determined in the following manner:

Selected Time = 0.081 minute

Rating Factor = 115 per cent

Normal Time =  $0.081 \times \frac{115}{100} = 0.093$  minute

**Time Study Summary.** After the normal time values are calculated for each element a summary is made on the back of the observation sheet in the space provided. A fatigue and personal allowance is determined for each element and recorded in the appropriate column. Twelve per cent is allowed for the first and fourth elements and 15 per cent for the second and third elements. These allowances are obtained from a table similar to the one shown in Fig. 247. No other allowances are made.

SUMMARY					
NO.	ELEMENTS	NORMAL TIME	FATIG & PERSONAL ALLOW.	OTHER ALLOW.	TOTAL ALLOW.
1.	Fill core box with 3 handfuls of sand. Press sand down each time.	.093	12	—	12
2.	Press sand down with one trowel stroke. Strike off with one trowel stroke.	.074	15	—	15
3.	Get and place plate on core box, turn over, rap, and remove box.	.170	15	—	15
4.	Carry plate with core 4 feet. Dispose on oven truck.	.040	12	—	12
					.429

FIG. 251. Part of observation sheet for "Make Core for Crank Frame." The Normal Time, Allowances, and the Standard Time for each element are shown.

See Fig. 248 for complete study.



OBSERVATION SHEET														
DEPARTMENT		Shoe Room		DATE		8-5-1947		OBSERVER		R. J. Parson				
FOREMAN		W. M. Wilson		OPERATOR		Betty Walker								
OPERATION		Assemble and Cement Heel Plugs on Swing Boot Insoles												
NO.	ELEMENTS	TIME												
		1	2	3	4	5	6	7	8	9	10	11	12	
1.	Get Supply of Heel Plugs	20 Pr.	.06	.07	.14	.07	.08	.08	.06	.08	.09	.10	.08	.09
2.	Get Supply of Insoles	20 Pr.	.12	.13	.10	.10	.13	.11	.12	.14	.13	.15	.13	.13
3.	Get, Loosen, and Lay Out Insoles in 15 Piles	7 1/2 Pr.	.41	.43	.42	.37	.44	.45	.42	.43	.46	.44	.43	.43
4.	Get, Pick, and Spot Heel Plugs on Insole	1/2 Pr.	.04	.05	.05	.09	.07	.06	.05	.04	.04	.05	.05	.05
		1/2 Pr.	.05	.05	.05	.07	.05	.06	.07	.04	.05	.05	.04	.05
		1/2 Pr.	.07	.05	.06	.05	.04	.06	.05	.05	.05	.05	.05	.07
5.	Get Brush of Cement, Cement, and Aside Brush	7 1/2 Pr.	.24	.26	.23	.23	.18	.22	.19	.23	.22	.26	.23	.23
6.	Stack Completed Work	30	.26	.24	.19	.24	.25	.23	.18	.20	.24	.19	.26	.26
7.	Mark Size on Stack	30	.04	.03	.04	.03	.02	.04	.05	.05	.04	.03	.03	.06
8.	Aside Completed Work	30	.04	.07	.05	.03	.04	.02	.04	.05	.08	.06	.03	.03
9.	Get Cement Supply	2000	.12	.08	.09	.08		.06	.08	.06	.08	.09	.08	.08
10.	Empty and Clean Cement Pan	2000	1.23	1.20	1.19	1.23								
11.	Clean Up Work Place and Cover Work	2000	1.06	1.05	1.11	1.08								
12.	Record Production	120	(From Standard Data)											
INFREQUENT ELEMENTS		OCCURRENCE	TIME	RATING	NORM. TIME									





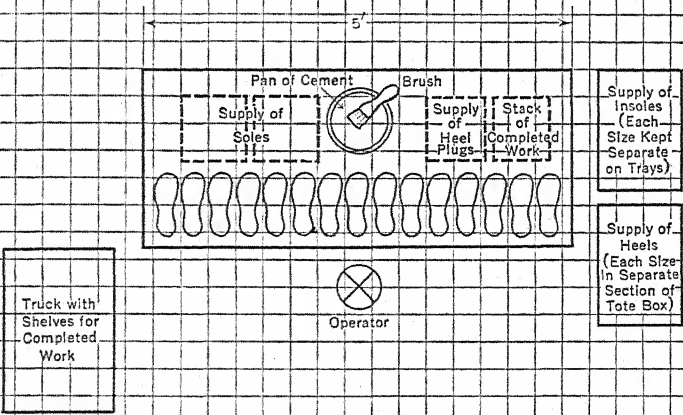
EQUIPMENT USED	PART DRAWING			
Work Bench	 <p style="text-align: center;">Sole</p>  <p style="text-align: center;">Heel Plug</p>			
Pan of Cement and Brush				
DISPOSITION OF COMPLETED WORK: Onto Truck with Shelves (T431)				
MATERIALS AND SUPPLIES				
DESCRIPTION	PAIRS PER UNIT	SOURCE	SUPPLIED BY	HOW SUPPLIED
Cement # CT 1031		Tank	Operator	
SKETCH OF WORKPLACE		SCALE: $\frac{1}{2}'' = 1'$		
				

Fig. 253. Back of observation sheet—assembling and cementing operation.



COMPUTATION SHEET					
OPERATION <u>Assemble and Cement Heel Plugs on Swing Boot Insoles</u>					
DEPARTMENT <u>Shoe Room</u> DATE <u>8-5-47</u>					
NO.	ELEMENTS	NORMAL TIME PER ELE- MENT	UNITS PER ELE- MENT (Pr.)	OCCUR. OF ELE- MENT PER 100 Pr.	NORMAL TIME PER 100 Pr.
1	Get Supply of Heel Plugs	.083	20	5	.415
2	Get Supply of Insoles	.133	20	5	.665
3	Get, Loosen, Layout Insoles in 15 Piles	.473	7½	13¾	6.292
4	Get, Pick, and Spot Heel Plugs on Insoles	.056	½	200	11.200
5	Get Brush of Cement, Cement, and Aside Brush	.219	7½	13¾	2.919
6	Stack Completed Work	.242	30	3¾	.807
7	Mark Size on Stack	.044	30	3¾	.147
8	Aside Completed Work	.063	30	3¾	.276
9	Get Cement Supply	1.200	2000	.05	.060
10	Empty and Clean Cement Pan	1.180	2000	.05	.059
11	Clean Up Work Place and Cover Work	1.948	2000	.05	.098
12	Record Production	.07	120	.83	.058
(A) TOTAL NORMAL TIME IN MINUTES					22.996
(B) ALLOWANCES (10%) IN MINUTES					2.299
(C) TOTAL STANDARD TIME PER 100 Pr. (A + B = C)					25.3
(D) DAY WORK HOURLY PRODUCTION					237 Pr.

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FIG. 254. Computation sheet for assembling and cementing operation.



The standard time is determined for each element in the following manner:

$$\text{Standard Time} = \text{Normal Time} + [(\text{Normal Time}) \times (\text{Allowances in Per Cent})]$$

For Element 1 this is:

$$\text{Standard Time} = 0.093 + (0.093 \times 0.12) = 0.093 + 0.011 = 0.104 \text{ minute}$$

In a like manner the standard time is determined for each of the four elements. (See Fig. 251.) Then these are added together to give the standard time for the cycle. Since one piece is produced per cycle, the standard time per piece is the same as the standard time per cycle.

A helper supplies the core maker with core sand and plates and provides empty core-oven trucks; therefore no time is included in the standard for this work. Had this been part of the core maker's job, this would have been timed and included as additional elements in the operation.

**Stop-Watch Time Study of an Assembling and Cementing Operation.** Figures 252 and 253 show the observation sheet for an assembling

PIECE-WORK RATE SHEET			
<b>DEPARTMENT</b>	Shoe Room	<b>DATE EFFECTIVE</b>	8-21-47
<b>OPERATION</b>	Assemble and cement heel plugs on insoles		
<b>TYPE SHOE</b>	Womens', misses', and child's swing boots		
	Womens', misses', and child's all-weather boots		
<b>JOB NUMBER</b>	16-16	<b>DAY WORK</b>	
	16-15	<b>PIECE WORK</b>	
<b>DAY WORK RATE</b>		<b>DAY WORK HOURLY PROD.</b>	<b>PIECE WORK RATE PER 100 PAIRS</b>
.70	Assemble and cement heel plugs on insoles	237 Pr.	\$0.30
APPROVED _____		J. S. Fuller	
APPROVED _____		Earl Stone	
		SUPT. HEAD OF TIME STUDY	

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Fig. 255. Piece-work rate sheet for assembling and cementing operation.



and cementing operation in a rubber-footwear plant. Figure 254 shows the Computation Sheet, and Figure 255 the Piece-Work Rate Sheet which is the authorization to put the piece rate into effect. The forms mentioned above are a part of the time study manual shown in Appendix C.

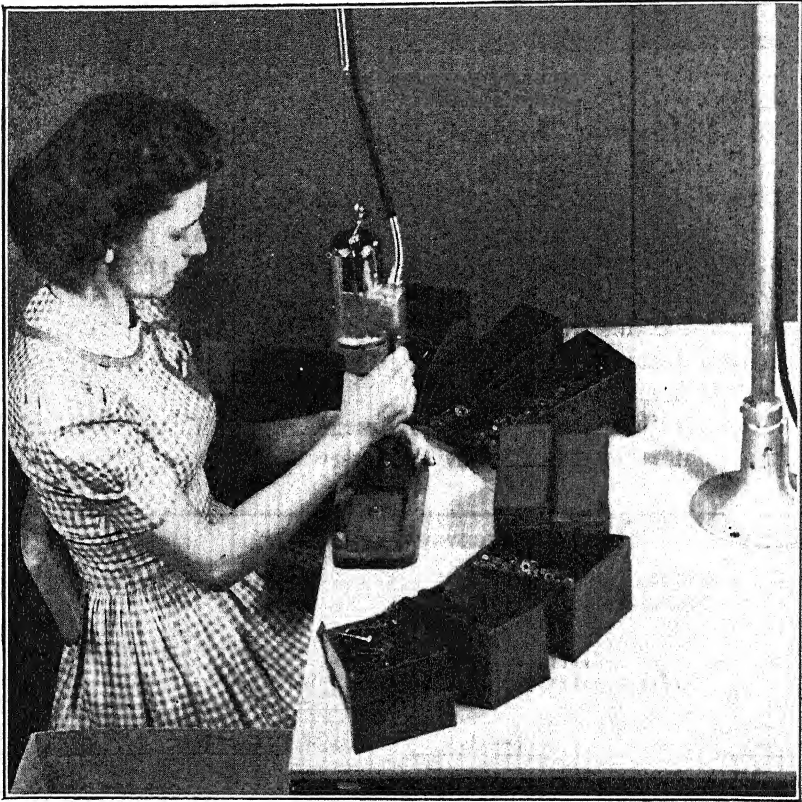
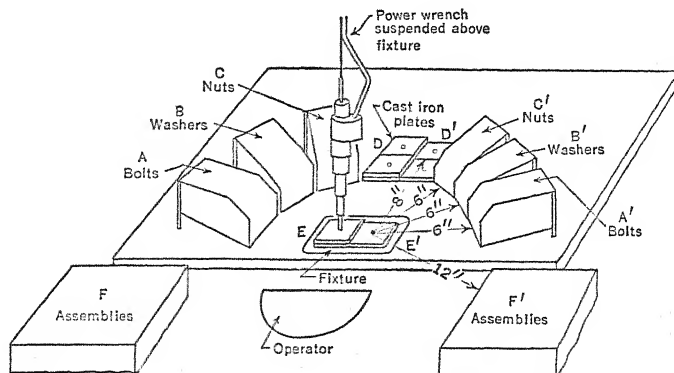


Fig. 256. Layout of work place for assembly of cast-iron plates. Power wrench is suspended above the fixture.

**Left- and Right-Hand Operation Description.** Many time study problems are created because the method used in performing the operation has not been recorded on the observation sheet in sufficient detail. One way to aid in solving this problem is to make a left- and right-hand description of each element of the operation. It may take the form of a record of each motion of each hand (see Figs. 63 and 79) or it may consist of a record of get, place, use, hold, dispose, and wait (see Figs. 256 and 257) for each hand. Figure 257 contains such a descrip-



# LEFT- AND RIGHT- HAND DESCRIPTION



Element No.	Left-Hand Description	Element No.	Right-Hand Description
1.	GET nut from bin C at left (6") PLACE nut in nest on LH side of fixture E (6") GET washer from bin B at left (6") PLACE washer in nest on top of nut (6")	1.	GET nut from bin C' at right (6") PLACE nut in nest on RH side of fixture E' (6") GET washer from bin B' at right (6") PLACE washer in nest on top of nut (6")
2.	GET first plate from pile D in front of fixture (8") PLACE first plate against guides on LH side of fixture E (8") GET second plate from pile D in front of fixture (8") PLACE second plate against guides on LH side of fixture E (8")	2.	GET first plate from pile D' in front of fixture (8") PLACE first plate against guides on RH side of fixture E' (8") GET second plate from pile D' in front of fixture (8") PLACE second plate against guides on RH side of fixture E' (8")
3.	GET washer from bin B at left (6") PLACE washer on left plate near center hole (6") GET bolt from bin A at left (6") PLACE bolt through hole in washer and assemble bolt through hole in plates (6"). Turn bolt one or two turns to start threads into nut	3.	GET washer from bin B' at right (6") PLACE washer on right plate near center hole (6") GET bolt from bin A' at right (6") PLACE bolt through hole in washer and assemble bolt through hole in plates (6"). Turn bolt one or two turns to start threads into nut
4.	GET—grasp plates on LH side of fixture E (1") HOLD plates " " GET—grasp plates on RH side of fixture E' (4") HOLD plates " "	4.	GET power wrench suspended above fixture (12") PLACE power wrench over head of left bolt (12") USE—Tighten bolt into nut. Drive $\frac{3}{4}$ " threads at 1200 r.p.m. PLACE power wrench over head of right bolt (4") USE—Tighten bolt into nut. Drive $\frac{3}{4}$ " threads at 1200 r.p.m. PLACE power wrench in position above fixture (12")
5.	GET finished assembly at left E (4") PLACE—dispose of assembly into tote box at left F (12")	5.	GET finished assembly at right E' (12") PLACE—dispose of assembly into tote box at right F' (12")

FIG. 257. Left- and right-hand operation description for the assembly of cast-iron plates.



tion of the elements of the cast iron plate assembly. This left- and right-hand description would be attached to the observation sheet and the time study would be made in the usual way.

As more time study analysts are trained in micromotion study, there is certain to be greater use of the left- and right-hand operation description. This more complete description of the operation is certain to make for a better time study.

**Production Studies.** Although a motion and time study may be made with care and the instruction sheet for the operation prepared and given to the operator, there is sometimes a complaint made by the operator that he is unable to perform the task in the time called for on the instruction sheet. If, after a preliminary check, it appears that the inability to do the task in the time set is not the fault of the operator, it is essential that a new study be made to check the original stop-watch time study. This new study is sometimes called a "production study" in that it covers a longer period of time than the original study—sometimes as long as a day or two. Figure 258 shows a production study summary.

The inability of the operator to perform the task in the time specified may be due to any one or a combination of these causes: conditions of material, tools, or equipment that are different from those existing at the time the original study was made; change in method, layout, or working conditions; operator has not had sufficient experience on the job or is unsuited to the work; or errors in the time study itself. The production study should be made in such detail as to permit the checking of elemental times.

Although every effort should be made to prevent errors in setting the original time standard, it is essential that the management be willing at all times to rectify errors or to demonstrate the correctness of the time standard. The workers must have confidence in the standards and in the men who set them.

**Random-Check Delay Studies.** L. H. C. Tippett of the British Cotton Industry Research Association has used a novel method for making delayed studies<sup>2</sup> which in some cases may be superior to production studies for determining the percentage of the day that a machine is running and the percentage of the day that it is idle, and the reasons for the idleness.

<sup>2</sup> Tippett, L. H. C., "Statistical Methods in Textile Research. A Snap-Reading Method of Making Time-Studies of Machines and Operatives in Factory Surveys," *Journal of the Textile Institute Transactions*, Vol. 26, February, 1935, pp. 51-55.



PRODUCTION STUDY SUMMARY

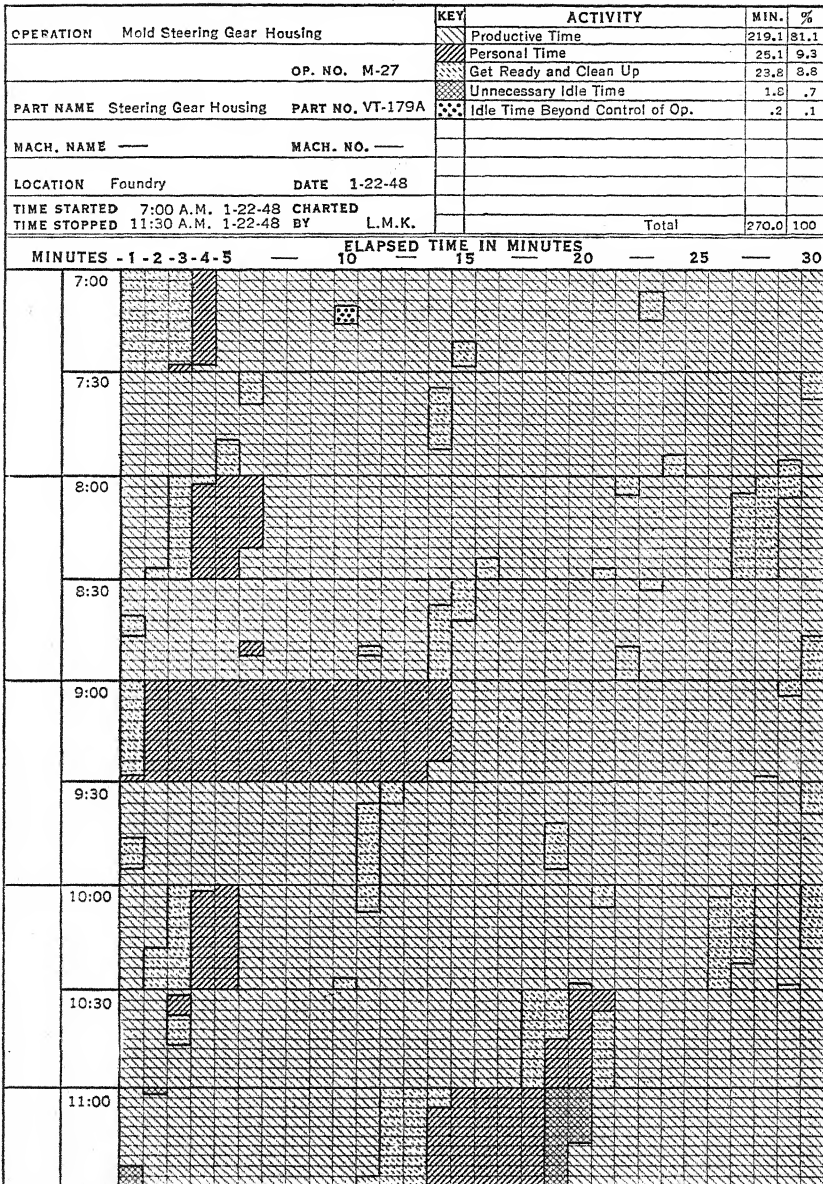


FIG. 258. Production study summary of a foundry operation covering a 4½-hour period. Size of sheet 8½ × 11 inches.



If a machine may be either running or idle, and if a large number of instantaneous observations are made at random intervals of its state, the percentage of the number of readings that indicate that the machine was running will tend to equal the percentage of the time that it was actually running. Likewise, if spot observations are made of the reason for the machine's being idle, the percentage of observations for any specific reason will be an indication of the percentage of the day that the machine was idle due to this particular reason.

From Tippett's experience it seems that to be reliable these delay studies must be made at random, and sufficient time must be allowed between readings so that the same delay is not recorded twice. That is, observations must be made at all hours of the working day, and not at periodic intervals. There must be a clear definition of the activity, such as when the machine will be considered idle and when running. Many observations must be made over a long period of time, and all observations must be made by the observer when he is at exactly the same relative position with respect to the machine. The cooperation of the operators must be obtained so that they will go about their work in the usual way, and so that they will not change their procedure when the observer approaches their machine.

**An Application of the Random-Check Method.** D. S. Correll made a random-check delay study of fourteen different machines in the University of Iowa laundry to determine the percentage of idle time and working time for each of these machines.<sup>3</sup> On the floor plan of the laundry he marked an X beside each machine that he planned to study to indicate the point at which he would make his observations. He prepared a written definition of the working time and idle time and also of the classification of idle time that he wanted to investigate. Then over a 2-month period and at random he made the circuit through the laundry, recording on his data sheet the state of each machine. If the operation was in the delay state the cause for the delay was determined and recorded.

A total of 5309 observations of all operations were made. The total number of delays amounted to 190 or 3.6 per cent of the total number of observations. The results of this study would indicate that during the 2-month period the fourteen jobs studied operated 96.4 per cent

<sup>3</sup> For other applications see: Morrow, R. L., "Time Study and Motion Economy," p. 175, Ronald Press, N. Y.; E. H. Schaeffer, "Observation Ratios," *Factory Management and Maintenance*, Vol. 99, No. 7, p. 58, July, 1941.



of the 8-hour day and that the delay time amounted to 3.6 per cent of the day. The analysis of the delays for all operations is given below.

## ANALYSIS OF DELAYS

Type of Delay	Number of Delays	Per Cent	Per Cent of Day
Talking	40	21	0.76
Change tote boxes	31	16	0.58
Transport material	30	16	0.58
Material setup	27	14	0.50
Turn storage boxes	17	9	0.32
Walking	13	7	0.25
Wait for machine	11	6	0.22
Personal	9	5	0.18
Miscellaneous	8	4	0.14
Machine	4	2	0.07
Total	190	100	3.60

**Recording and Filing.** When a stop-watch study is to be made of a series of similar operations it is desirable to define carefully each of the elements in order that standard-time data for each element may finally be determined. For example, in the operation "solder side seam of rectangular can" the elements are defined (see page 414), and irrespective of the person making stop-watch studies of soldering work this uniform division of the operation into elements will be made. A master form is prepared, and the essential data from each stop-watch study of soldering side seams are recorded on this sheet. After sufficient data have been accumulated they will be used for setting up formulas for synthetically determining time standards on soldering operations as illustrated in Chapter 24.

Stop-watch studies together with other data and information concerning the operation should be filed in such a way that they may be readily located when needed. Cross indexing is often worth while.

**Guaranteed Time Standard.** The time standard should be guaranteed against change unless there has been a change in method, materials, tools, equipment, layout, or working conditions; or when there has been a clerical error or a mistake in the calculation of the standard.



When a time standard is set for a job it is understood that the operator must perform the operation exactly as specified in the standard practice or on the instruction sheet. If the operation is not performed in this manner, the time standard is not effective. However, so long as the operator does the job in the prescribed manner, the company guarantees that the time standard will not be changed. The company should adhere to this policy so completely that every operator will feel free to work at whatever pace he chooses. The operator should have no fear that the time standard for the job will be reduced if he "earns too much" under a wage-incentive system.

**Methods Change.** When there is a change in method, materials, tooling, or other factors affecting the time of the operation, there should be a re-study made of the job, and a new time standard should be established. If the operator suggests a change which reduces the operation time, improves the quality, or makes the job safer, the worker should be compensated immediately for his suggestion. If the company has a suggestion system he should be rewarded through the regular channels. When the new standard for the improved job has been established, the operator should find it just as easy to earn his accustomed incentive premium or bonus as he did before the method was improved. A change in method should not be used as an excuse to reduce a time standard. If management expects to get and maintain the cooperation of its employees, it must make certain that the employee gains and does not lose as a result of his suggestions.

**Time Study As a Staff Activity.** The time study department is a staff department and not a line or operating agency. (See Figs. 259 and 260.) It is important that every industrial engineer keep this fact fixed firmly in his mind. Since a staff department must work through the foremen and supervisory groups, it is important that the line personnel be thoroughly acquainted with principles, techniques, and methods of the time study department. Foremen should be so well acquainted with time study that they can explain to an operator in the department how a time study is made, what elements are included in the operation, and exactly how the time standard for an operation is determined. The foreman should be able to do this without having to call on the time study department for help. Of course, in unusual situations, the foreman may have to ask the time study department for additional information, or in some cases it might be wise for the time study man to supplement the information given to the operators by the foreman.



Sometimes it is helpful to draw a parallel between two unrelated activities in order to clarify a situation. Guy J. Bates of General Motors has used this analogy: When the number of rejects in a manufacturing department suddenly increases and the operator on the machine states that the cause is due to the inspection gauge being out of adjustment, the foreman would ordinarily examine it to see if anything was obviously wrong and would gauge some parts himself to make certain that the operator was using the gauge properly. If no cause for the difficulty could be found, the foreman would call the head of the inspection department and have him check the gauge. The fore-

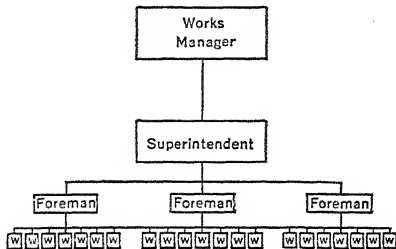


FIG. 259. Typical line organization.

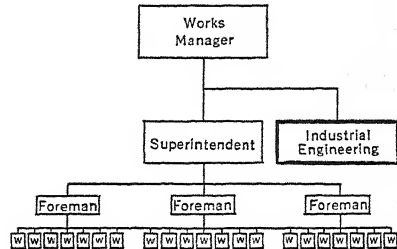


FIG. 260. Line and staff organization showing typical staff department.

man might be present while the check was being made, but the foreman would expect the chief inspector to make any measurements that seemed necessary to determine whether the excessive number of rejects was due to a faulty gauge. So with time study work—just as the inspector and the tool department build, service, and check all gauges and inspection devices, so the time study department sets all time standards and maintains them. If an operator complains that the time standard is too low and that he cannot earn a premium, the foreman would be expected to check the operation against the instruction sheet to see whether the operation was being performed according to the prescribed method. This involves checking the materials, speeds, and feeds of the machine, and other job conditions. If after checking these things, the foreman is unable to find a cause for the apparent error in the standard, he would request that a time study man be sent to the department to check the standard. The foreman might or might not remain with the time study man while the check study was being made, but he would certainly follow in detail the checking procedure and would know the cause of the difficulty and the means that finally were used to correct the situation.



As in the case of all staff functions in the plant, it is necessary to have a careful balance between the duties of the industrial engineering department and line departments. Although the time study department is definitely responsible for establishing and maintaining time standards in a plant, the industrial engineer works through the foreman and does not replace the foreman. Of course an indifferent, lazy, or antagonistic foreman may not give wholehearted cooperation. In such situations, this attitude is a challenge to the time study department and to top management to show the foreman why it is to his advantage, to the advantage of the company, and to the advantage of the operators in his department to understand time study and to carry out the procedures established by the organization with regard to the administration of time study and wage incentives.



## CHAPTER 23

### DETERMINING TIME STANDARDS FROM ELEMENTAL TIME DATA AND FORMULAS

Many stop-watch time studies are made of a single operation with little or no idea that the data taken will be of value on any other operation. There are, however, some kinds of work that have certain elements which are alike. For example, in a given class of machine-tool work all elements may be virtually alike except for the machine time or the cutting time. Thus the same jig used for drilling the  $\frac{1}{4}$ -inch hole in the end of the shaft (see Fig. 238 on page 345) might also be used for drilling many other sizes of shafts. If the length and the diameter of the shafts fall within a limited range, handling time for drilling all shafts would be practically constant, and the only variable in the operation would be the time required to drill the hole, which would vary with its diameter and depth. Other operations using jigs similar to this one would have certain elements in common such as "tighten set screw" or "lower drill to work."

Where motion and time studies are to be made of many different operations of a similar class of work, such as that on sensitive drill presses, lathes, and gear hobbers, it is best to consider the entire class of work as a unit, working out such improvements in methods as seem advisable, and standardizing all factors for the entire class of work. When the stop-watch time studies are begun on this work, the elements should be selected in such a way as will make it possible eventually to construct tables of standard-time data that may be applied to all elements likely to appear continually in that particular class of work.

**Use of Time Values for Constant Elements.** The data shown in Tables XXIII to XXV were obtained from a sufficient number of stop-watch studies of representative kinds of work to guarantee their being reliable. With such data available in the time study department,<sup>1</sup> it is possible to set time standards for the handling elements of any job on a sensitive drill falling within the classes listed in Tables XXIV

<sup>1</sup> For other elemental time data for drilling, see Ralph M. Barnes, "Industrial Engineering and Management," pp. 134-135, McGraw-Hill Book Co., New York, 1931.



and XXV. These data do not give the time required to drill the hole in the piece; consequently this information must be obtained by means of a stop-watch time study of this element.

TABLE XXIII  
TIME-SETTING DATA FOR SENSITIVE DRILLS  
Setup Time

Description of Work	Time, Minutes
1. Small work held in jig which can be handled very easily by hand	15.00
2. Small work held in vise	15.00
3. Small work held to table by one or two straps	15.00
4. Small work held in jig having a number of drilled, tapped, and reamed holes	30.00
5. Small work held in jig and jig held in vise	30.00
6. Work of medium size held by one or two straps	30.00
7. Work of medium size prevented from turning on table by a stop in T-slot	15.00
8. Work of circular type such as washers, collars, bushings, and sleeves held to table by a draw bolt through center	15.00

Assuming that Tables XXIII, XXIV, and XXV were available and that it was necessary to determine the standard time to drill the  $\frac{1}{4}$ -inch hole in the end of the shaft (Fig. 238 on page 345), the procedure would be as follows:

Chuck and remove piece (from Table XXIV) (Class B, work held by set screw)	0.50
Machine manipulation (from Table XXV) (Class A, drilling, one drill and no bushing)	0.07
DRILL $\frac{1}{4}$ -INCH HOLE (stop-watch data obtained as in Fig. 238)	0.54
Total normal time per piece	1.11
5 per cent allowance	0.06
Total standard time per piece	1.17 minutes
Setup time (from Table XXIII) = 15.00 minutes	

The value of standard-time data such as those illustrated above is evident. They reduce the number of stop-watch time studies needed, shorten the time required to set the standard, and tend to bring greater accuracy and uniformity in time standards for a given class of work.



The next step in this direction is the preparation of formulas which will make it possible to calculate quickly time values for the machine elements. Thus, with standard-time data for the handling

TABLE XXIV

## ELEMENTAL TIME DATA FOR SENSITIVE DRILLS

## Chuckling and Removing Time

## 1. Work Held in Jig

## Classes:

- A. Held by thumb screw
- B. Held by set screw
- C. Held by thumb and set screw
- D. Held by cover strap and thumb screw
- E. Held by cover strap and set screw
- F. Held by cover strap, thumb screw, and set screw

Elements	Time, Hundredths of a Minute					
	A	B	C	D	E	F
1. Pick up piece and place in jig	12	12	12	12	12	12
2. Swing cover strap and tighten lock screw	..	..	..	10	10	10
3. Tighten thumb screw	08	..	08	08	..	08
4. Tighten set screw	..	12	12	..	12	12
5. Loosen set screw	..	06	06	..	06	06
6. Loosen thumb screw	05	..	05	05	..	05
7. Swing cover strap back and loosen lock screw	..	..	..	08	08	08
8. Remove piece from jig	08	08	08	08	08	08
9. Blow out chips	12	12	12	12	12	12
Total	45	50	63	63	68	81

*Note.* Add 0.32 minute when jig is strapped to table. Add 0.07 minute for each additional thumb screw. Add 0.08 minute for each additional set screw.

elements and calculated time values for the machine elements, it is possible to determine the time standard for a given operation without the necessity of making a stop-watch study at all. By using this procedure the time standard can readily be determined in advance of the actual production of the part. In this case a detailed drawing of the part to be made and the operation sheet or the route sheet should be supplied to the time study department in advance.



TABLE XXV

## ELEMENTAL TIME DATA FOR SENSITIVE DRILLS

## Machine Manipulation Time

Classes:

- A. Drilling, one drill and no bushing
- B. Drilling, placing and removing bushing
- C. Drilling, placing and removing drill
- D. Drilling, placing and removing drill and bushing

Elements	Time, Hundredths of a Minute			
	A	B	C	D
1. Place bushing in jig	..	06	..	06
2. Place drill in chuck	..	..	04	04
3. Advance drill to work	04	04	04	04
4. Raise drill from hole	03	03	03	03
5. Remove bushing from jig	..	05	..	05
6. Remove drill from chuck	..	..	03	03
Total	07	18	14	25

*Note.* Add 0.15 minute when quick-change chuck is not used (cases B and C). Add 0.06 minute for advancing work to next spindle. Add 0.05 minute when reamer is oiled before entering hole.

**Determining Time Standards for Variables.** On all kinds of machine tool work the time for manipulating the machine and for chucking and removing the piece is likely to remain constant for each element, provided the size and shape of the piece are within reasonably close limits. The time for making the cut is the variable. This machine time can often be calculated, particularly when positive power feeds are used. For example, in milling-machine work with power feed, if the feed of the table in inches per revolution of the cutter is known, and if the speed of the cutter in revolutions per minute is known, it is a simple arithmetical problem to find the time required to mill a piece of a given length. An allowance must be added to the length of the piece for the approach and for the overtravel of the cutter; however, they can also be calculated easily. In a similar manner, if a shaft of a given length is chucked in a lathe, and if the



speed and the feed are known, it is a simple matter to calculate the length of time required to make a cut across the piece. Therefore, on machine tool work the handling time (a constant) plus the machine time (a variable) plus allowances will equal the standard time for the performance of a given operation.

In the operation of soldering the side seam in making rectangular cans (see pages 414 to 418) the principal variable is the element "solder the full length of the seam." The time for this element varies directly as the length of the seam.

#### SETTING TIME STANDARDS FOR MILLING SQUARE OR HEXAGON ON BOLTS, SCREWS, OR SHAFTS

With the aid of the following four tables it is possible to determine the time standard for setting up a milling machine and for milling a square or hexagon on the end of bolts, screws, or shafts. The data in Tables XXVI and XXVII were determined from stop-watch time studies. A sufficient number of representative jobs were studied to give reliable data. Tables XXVIII and XXIX were compiled to facilitate the determination of the time standard for a given operation. Typical examples at the bottom of these two tables show how they are used.

There are two methods of milling squares and hexagons: (1) using a single mill, which requires a separate cut for each side (use Table XXVIII), and (2) using a gang mill, which cuts two sides at a time (use Table XXIX).

**Computation of Data for Table XXVIII—Milling by Use of 6-Lip Mill.** This milling operation is performed with a single milling cutter; hence four cuts are required to mill a square and six cuts to mill a hexagon. The dimension  $B$  (see sketches in Tables XXVIII and XXIX) is given as the turned diameter of the shaft rather than the width of the face to be cut, for the reason that detailed drawings (see Fig. 261) are dimensioned in that manner. Since the side of a square is equal to 0.7071 times the diameter of the circumscribed circle and since the side of a hexagon is equal to the radius of the circumscribed circle, it is easy to make the conversion.

When a single mill is used the cut is made across the face, and the time for the cut varies as  $B$  and is independent of the dimension  $A$ , provided it falls within the scope of the data, that is, within  $\frac{5}{8}$  inch to  $1\frac{3}{4}$  inch. The total handling time ( $HT$ ) plus the total cutting time ( $M$ ) plus the allowances equal the total time for the operation.



TABLE XXVI  
TIME-SETTING DATA FOR MILLING MACHINES  
Machine Class 36

Setup Time

1. *Base Setup Times*

Time in Minutes

Type	Work Sizes		
	Small	Medium	Large
A. Strapped to table or angle plate (4 straps)	25	25	25
B. Held in vise . . . . .	25	25	25
C. Held in 2 vises . . . . .	..	30	30
D. Vise with false jaws . . . . .	35	35	35
E. Held in fixture . . . . .	35	45	60
F. Held in dividing head chuck . . . . .	35	35	..
G. Held in dividing head and tail stock . . . . .	45	45	..

2. *Additional Parts Used*—Time to Be Added to Base Setup Time

Part	Part Sizes		
	Small	Medium	Large
H. Each additional strap . . . . .	5	5	5
J. Angle plate . . . . .	10	15	15
K. Gang mills			
(1) fractional limits . . . . .	10	10	10
(2) decimal limits . . . . .	15	15	15
L. False table . . . . .	10	15	20
M. Round table—hand feed . . . . .	10	20	20
N. Round table—power feed . . . . .	20	30	30
P. High-speed head . . . . .	..	40	..
Q. Universal head . . . . .	..	60	..



TABLE XXVII

ELEMENTAL TIME DATA FOR MILLING SQUARE OR HEXAGON ON BOLTS, SCREWS,  
OR SHAFTS

Machine Class 36

Milling Table 1A

1. *Setup time*—Complete—See setup table  
Change size — End mill — 10 min.  
Gang mills — 20 min.
2. *Specifications*—  
A. Method of chucking—1—3-jaw chuck (small screws and bolts)  
2—Held on centers (shafts)  
3—Thread arbor in dividing head (small pieces with thread on or in end)  
B. Cutters—1—6-lip mill  
2—Gang mills (6-in. stagger tooth—side milling cutters)  
C. Length of flat —  $\frac{3}{8}$  in.— $1\frac{3}{4}$  in.  
D. Size of sq. or hex. —  $\frac{1}{2}$  in.— $1\frac{5}{8}$  in.  
E. Number of cuts — 1 per side  
F. Material — SAE2315  
G. Indexing — Use rapid index plate wherever possible
3. *Operation Time*.—Machine manipulation and chucking time  
Time in Minutes

Method of Chucking												
Elements	1					2		3				
	Square		Hex.		Sq.		Hex.		Square		Hex	
	Speed r.p.m.											
	214	58	214	58	214	214	214	58	214	58		
	Type of Mill	6-Lip Mill	Gang Mill	6-Lip Mill	Gang Mill	6-Lip Mill	6-Lip Mill	6-Lip Mill	Gang Mill	6-Lip Mill	Gang Mill	
1. Stop machine..	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	
2. Loosen dog in holder.....	.....	.....	.....	.....	0.08	0.08	.....	.....	.....	.....	.....	
3. Loosen center..	.....	.....	.....	.....	0.08	0.08	.....	.....	.....	.....	.....	
4. Loosen work..	0.04	0.04	0.04	0.04	.....	.....	0.03	0.08	0.08	0.08	0.08	
5. Remove work..	0.06	0.06	0.06	0.06	0.10	0.10	0.08	0.08	0.08	0.08	0.08	
6. Remove dog..	.....	.....	.....	.....	0.08	0.08	.....	.....	.....	.....	.....	
7. Place dog.....	.....	.....	.....	.....	0.08	0.08	.....	.....	.....	.....	.....	
8. Clear chips....	.....	.....	.....	.....	0.05	0.05	0.08	0.08	0.08	0.08	0.08	
9. Place piece....	0.08	0.08	0.08	0.08	0.08	0.08	0.12	0.12	0.12	0.12	0.12	
10. Tighten.....	0.12	0.12	0.12	0.12	0.18	0.18	0.10	0.10	0.10	0.10	0.10	
11. Start machine..	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	
12. Advance to cut	0.04	0.06	0.04	0.06	0.04	0.04	0.04	0.06	0.04	0.06	0.06	
13. Change depth.	*	*	*	*	*	*	*	*	*	*	*	
14. Mill.....	2 7/8† or 3 3/8	M	M	M	M	M	M	M	M	M	M	
15. Index†.....	0.15	0.05	0.25	0.10	0.15	0.25	0.15	0.05	0.25	0.10	0.10	
16. Return table..	0.05	0.07	0.05	0.07	0.05	0.05	0.05	0.07	0.05	0.07	0.07	
TOTALS....	0.60	0.54	0.70	0.59	1.03	1.13	0.76	0.70	0.86	0.75	0.75	

\* Allow 0.08 when necessary.

† Feed in inches per minute—depending upon finish required.

‡ Above time is for rapid indexing. (Double indexing time when using precision crank.)

$$M = \text{Cutting time} = \frac{(L + OT) \times \text{No. cuts}}{\text{Feed}}$$

$$\text{Base time} = H.T. + M$$

$$\text{Standard time} = \text{Lase time} + \text{Allowances}$$



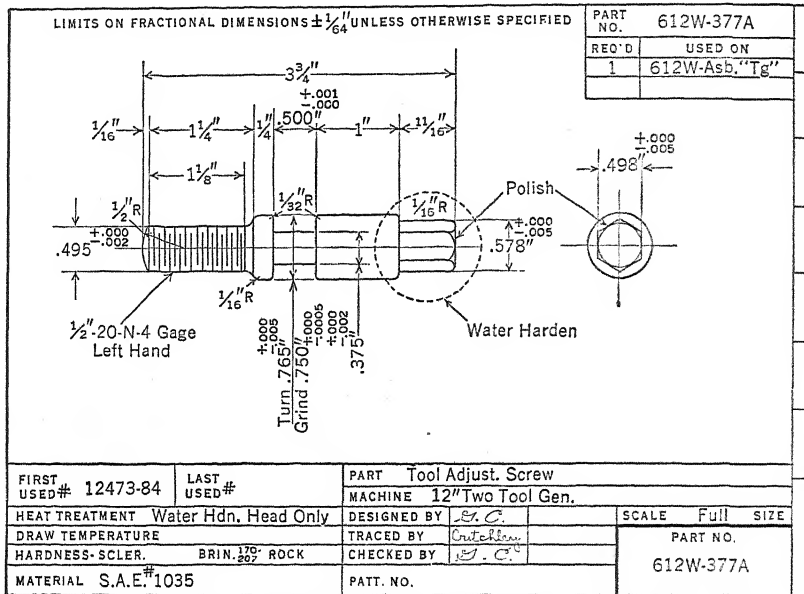


FIG. 261. Detail drawing of a tool adjusting screw, part G12W-377A.

The handling time is composed of machine-manipulation time and chucking and removing time as shown in Table XXVII. The cutting time can be calculated from the following formula:

$$M = \frac{(L + OT)N}{F}$$

where  $M$  = cutting time in minutes

$L$  = length of cut in inches

(a)  $L = 0.707 \times B$  for square

(b)  $L = 0.5 \times B$  for hexagon

$OT$  = overtravel =  $\frac{1}{2}$  diameter of mill in inches

$N$  = number of cuts per piece

(a)  $N = 4$  for a square

(b)  $N = 6$  for a hexagon

$F$  = table feed in inches per minute

(a) for fine finish use  $2\frac{7}{8}$  inches

(b) for ordinary finish use  $3\frac{5}{8}$  inches

*Example.* Assume that the shaft at the top of Table XXVIII has these dimensions:  $A = 1\frac{3}{4}$  inches;  $B = 1$  inch; ordinary finish (feed =  $3\frac{5}{8}$  inches per minute); mill square with  $1\frac{3}{4}$ -inch diameter, 6-lip mill; piece held in a 3-jaw chuck.



The handling time ( $HT$ ) is obtained from Table XXVII, under method of chucking, 1, square, 6-lip mill, and is 0.60 minute.

The cutting time is calculated from the above formula.

$$M = \frac{(0.707 + 0.875)4}{3.625} = \frac{6.328}{3.625} = 1.748$$

$$HT = 0.60$$

$$M = 1.748$$

$$\text{Total normal time} = 2.348$$

$$5 \text{ per cent allowance} = 0.117$$

$$\text{Total standard time} = 2.465 \text{ use 2.5 minutes}$$

$$L = 0.707 \times 1 = 0.707$$

$$OT = \frac{1}{2} \text{ of } 1\frac{3}{4} = \frac{7}{8}$$

$$N = 4$$

$$F = 3.625$$

Now with reference to Table XXVIII, since a single cutter is used and since  $A$  lies between the limits given, this table applies. Reading under symbol 8- $D$ , the standard time equals 2.5 minutes which checks with that calculated above.

**Computation of Data for Table XXIX—Milling by Use of Gang Mill.** This milling operation is performed with a gang milling cutter; hence two sides are cut at one time, two cuts being required for a square and three cuts for a hexagon. The direction of travel of the mill in making the cut is from the end toward the shoulder; hence the time for the cut varies as  $A$  and is independent of  $B$ , provided it falls within the scope of the data, that is, provided the diameter of the shaft is between  $\frac{1}{2}$  inch and  $1\frac{5}{8}$  inches.

The total standard time for the operation is equal to the handling time ( $HT$ ) plus the cutting time ( $M$ ) plus the allowances. The handling time is taken directly from Table XXVII, and the cutting time can be calculated from the following formula:

$$M = \frac{(L + OT)N}{F}$$

where  $M$  = cutting time in minutes

$L$  = length of cut =  $A$

$OT$  = overtravel—since the direction of travel of the gang mill is from the end to the shoulder, no overtravel is allowed.

$N$  = number of cuts per piece

(a)  $N = 2$  for a square

(b)  $N = 3$  for a hexagon

$F$  = table feed in inches per minute

*Example.* The operation is that of milling hexagon on Tool Adjusting Screw, Part No. G12W-377A, as shown in Fig. 261. The following information is taken

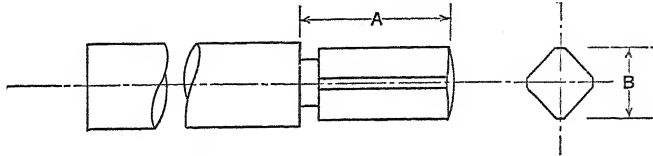


TABLE XXVIII

TIME-SETTING TABLE FOR MILLING SQUARE AND HEXAGON ON BOLTS, SCREWS, AND SHAFTS

Machine Class 36

Milling Table 1B



Case 1—Using a 6-Lip Mill (See Table 1C for Gang Mills)

Time per Piece in Minutes

Sym- bol	A (See Sketch Above)	B (See Sketch Above)	3-Jaw Chuck				On Centers				On Thread Arbor in Div. Head			
			Square		Hex.		Square		Hex.		Square		Hex.	
			Feed 2 7/8	Feed 3 3/8	Feed 2 7/8	Feed 3 3/8	Feed 2 7/8	Feed 3 3/8	Feed 2 7/8	Feed 3 3/8	Feed 2 7/8	Feed 3 3/8	Feed 2 7/8	Feed 3 3/8
			C	D	E	F	G	H	J	K	L	M	N	O
1	5/8 in. to 1 1/4 in.	1/2	2.4	2.1	3.2	2.7	2.9	2.5	3.7	3.2	2.6	2.3	3.4	2.9
2		9/16	2.5	2.1	3.3	2.8	3.0	2.6	3.7	3.2	2.7	2.3	3.5	2.9
3		5/8	2.6	2.1	3.3	2.8	3.0	2.6	3.8	3.3	2.8	2.4	3.5	3.0
4		11/16	2.6	2.2	3.5	2.9	3.1	2.7	3.9	3.4	2.8	2.4	3.6	3.1
5		3/4	2.7	2.3	3.5	3.0	3.2	2.8	4.0	3.4	2.9	2.5	3.7	3.1
6		13/16	2.8	2.3	3.6	3.0	3.3	2.8	4.1	3.5	3.0	2.5	3.8	3.2
7		7/8	2.8	2.4	3.6	3.1	3.3	2.8	4.1	3.6	3.0	2.6	3.9	3.3
8		1	3.0	2.5	3.8	3.2	3.4	3.0	4.2	3.6	3.1	2.7	4.1	3.3
9		1 1/8	3.1	2.6	4.0	3.3	3.5	3.0	4.4	3.7	3.3	2.8	4.2	3.4
10		1 1/4	3.2	2.7	4.1	3.4	3.7	3.2	4.5	3.9	3.4	2.9	4.3	3.6
11		1 3/8	3.3	2.8	4.2	3.5	3.8	3.3	4.7	4.0	3.5	3.0	4.4	3.7
12		1 1/2	3.5	2.9	4.4	3.6	4.0	3.4	4.8	4.1	3.7	3.1	4.5	3.8
13		1 5/8	3.6	3.0	4.5	3.7	4.1	3.5	5.0	4.2	3.8	3.2	4.7	3.9

- Values in this table vary as  $B$ , hence see that  $A$  falls within limits  $5/8$  in. to  $1 1/4$  in. before using data.
- These time standards are based on:
  - Length of travel =  $B + \text{overtravel}$
  - Handling time from Table 1A
  - Allowance of 5 per cent
- Examples for reading above table:
  - Let  $B = 5/8$  in.,  $A = 1$  in., Square head shaft, held on centers, 6-lip mill,  $3 3/8$  in. feed. Since  $A$  lies between limits given this table applies. Read from table under 3-H, standard time = 2.6 min. per piece.
  - Let  $B = 1 1/4$  in.,  $A = 1 1/2$  in., Hexagon head bolt, held on thread arbor in div. head, 6-lip mill,  $2 7/8$  in. feed. Since  $A$  lies between limits given this table applies. Read from table under 10-N, standard time = 4.3 min. per piece.

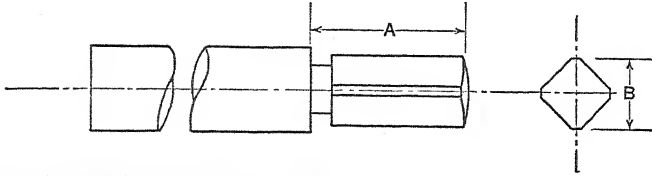


TABLE XXIX

TIME-SETTING TABLE FOR MILLING SQUARE AND HEXAGON ON BOLTS, SCREWS,  
AND SHAFTS

Machine Class 36

Milling Table 1c



Case 2—Using Gang Mills (See 1B for 6-Lip Mill)

Time per Piece in Minutes

Sym- bol	A (See Sketch Above)	B (See Sketch Above)	3-Jaw Chuck				On Thread Arbor in Div. Head			
			Square		Hex.		Square		Hex.	
			Feed 2 <sup>1</sup> / <sub>8</sub>	Feed 3 <sup>1</sup> / <sub>8</sub>	Feed 2 <sup>1</sup> / <sub>8</sub>	Feed 3 <sup>1</sup> / <sub>8</sub>	Feed 2 <sup>1</sup> / <sub>8</sub>	Feed 3 <sup>1</sup> / <sub>8</sub>	Feed 2 <sup>1</sup> / <sub>8</sub>	Feed 3 <sup>1</sup> / <sub>8</sub>
			C	D	E	F	G	H	J	K
1	<sup>5</sup> / <sub>8</sub>	$\frac{1}{2}$ in. to $1\frac{5}{8}$ in.	1.05	0.95	1.35	1.2	1.15	1.10	1.5	1.4
2	$1\frac{1}{16}$		1.10	1.0	1.40	1.25	1.25	1.15	1.6	1.4
3	<sup>3</sup> / <sub>4</sub>		1.15	1.05	1.5	1.25	1.35	1.20	1.7	1.5
4	$1\frac{3}{16}$		1.20	1.05	1.6	1.30	1.35	1.25	1.7	1.5
5	<sup>7</sup> / <sub>8</sub>		1.20	1.10	1.6	1.35	1.40	1.25	1.8	1.6
6	$1\frac{5}{16}$		1.25	1.15	1.7	1.45	1.45	1.30	1.8	1.7
7	1		1.35	1.20	1.8	1.50	1.50	1.35	1.9	1.7
8	$1\frac{1}{8}$		1.35	1.20	1.9	1.5	1.6	1.35	2.0	1.8
9	$1\frac{1}{4}$		1.40	1.25	1.9	1.6	1.6	1.40	2.1	1.8
10	$1\frac{3}{8}$		1.45	1.30	2.0	1.7	1.7	1.45	2.2	1.9
11	$1\frac{1}{2}$		1.50	1.30	2.1	1.8	1.7	1.5	2.2	2.0
12	$1\frac{5}{8}$		1.60	1.40	2.2	1.9	1.8	1.6	2.4	2.1
13	$1\frac{1}{2}$		1.7	1.45	2.3	2.0	1.9	1.6	2.5	2.2
14	$1\frac{3}{4}$		1.8	1.6	2.5	2.1	2.0	1.7	2.6	2.3
15	$1\frac{7}{8}$		1.9	1.6	2.6	2.2	2.1	1.8	2.7	2.4

1. Values in this table vary as A, hence see that B falls within limits  $\frac{1}{2}$  in. to  $1\frac{5}{8}$  in. before using data.

2. These time standards are based on:

- (a) Length of travel = A
- (b) Handling time from Table 1A
- (c) Allowance of 5 per cent

3. Examples for reading above table:

- (a) Let A = 1 in., B =  $1\frac{3}{16}$  in., Square head bolt, held in chuck, gang mill,  $3\frac{1}{8}$  in. feed. Since B lies between limits given this table applies. Read from table under 7-D standard time = 1.20 min. per piece.
- (b) Let A =  $1\frac{1}{16}$  in., B = 0.578 in., Hexagon head adjusting screw, held in chuck, gang mill,  $3\frac{1}{8}$  in. feed. Since B lies between limits given this table applies. Read from table under 2-F, standard time = 1.25 min. per piece.



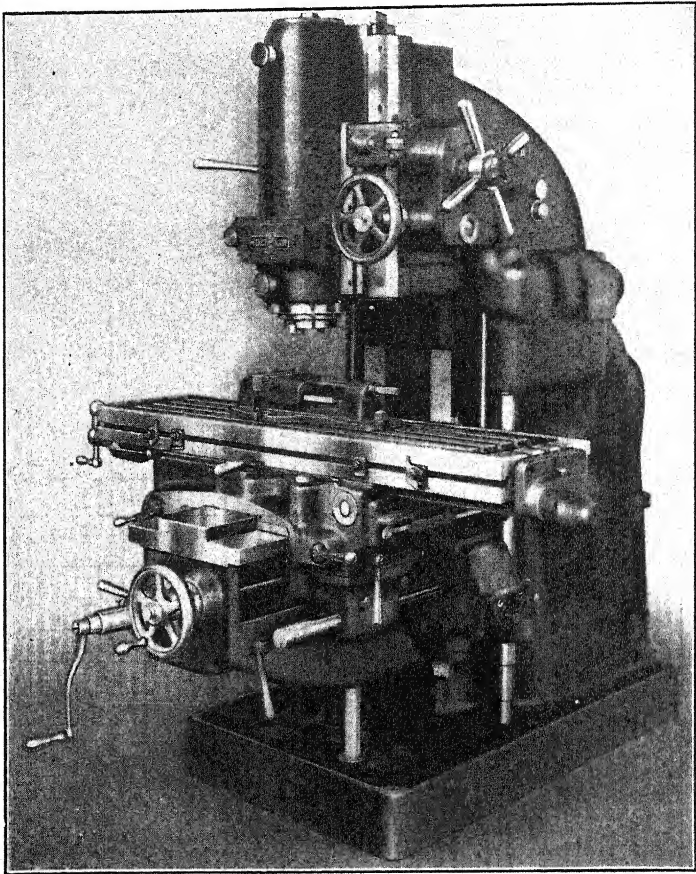


FIG. 262. Cincinnati vertical milling machine.

MACHINE DATA

Builder: Cincinnati Milling Machine Co.  
Name of Machine: Cincinnati

Machine Class 36—Mach. No. 1817  
Type of Machine: No. 3 Vertical

Specifications:

Table:  
Working surface.....56" × 16½"  
Size overall.....60¼" × 16½"  
  
Range:  
Longitudinal.....34"  
Cross.....14½"  
Vertical knee.....14"  
Head travel.....8"  
Quick traverse.....Power

Spindle:  
Size of taper.....14  
No. of spindle speeds.....16  
Range of spindle speeds.....15 to 414  
  
Feed:  
No. of feeds.....16  
Range of feeds.....½" to 20" per min.

Table Feeds (in Inches per Minute)

½	1⅜	3⅝	9¾
⅝	1¾	4¾	12½
¾	2¼	6⅝	16
1⅜	2⅞	7¾	20

Spindle Speeds in R.P.M.  
Pulley Runs at 600 R.P.M.

15	37	86	214
19	47	118	269
23	58	134	335
29	72	166	414



from the drawing (Fig. 261) and from the operation sheet (not shown):  $A = 1\frac{1}{16}$  inch,  $B = 0.578$  inch. 7-inch gang mill, ordinary finish,  $3\frac{5}{8}$  inches per minute feed, piece held in 3-jaw chuck.

Handling time from Table XXVII = 0.59 minute.

Cutting time is calculated from the above formula.

$$M = \frac{(0.6875 + 0)3}{3.625} = 0.569 \text{ minute}$$

$$L = 1\frac{1}{16} = 0.6875$$

$$OT = 0$$

$$N = 3$$

$$F = 3\frac{5}{8} = 3.625$$

Therefore the total time for the operation is:

$$HT = 0.59$$

$$M = 0.569$$

---


$$\text{Total normal time} = 1.159$$

$$5 \text{ per cent allowance} = 0.058$$

---


$$\text{Total standard time} = 1.217 \text{ use } 1.25 \text{ minutes}$$

Now with reference to Table XXIX, since a gang mill is used and since B lies between the limits given, this table applies. Reading under symbol 2-F the standard time equals 1.25 minutes, which checks with that calculated above.



## CHAPTER 24

### THE USE OF ELEMENTAL TIME DATA AND FORMULAS TWO CASES: GEAR HOBGING AND SOLDERING CANS .

#### TIME STANDARDS FOR GEAR HOBGING

The following example of the use of elemental time data and formulas for setting time standards of gear hobbing demonstrates how the principles already explained may be applied to rather complicated work. The data and procedure given here have been in constant use in a well-known machine-tool plant for a number of years and still serve their purpose satisfactorily.

Although the data apply to the cutting of both straight and helical spur gears, only those pertaining to cutting straight spur gears will be given here. These data are applicable to straight spur gears varying from 4 to 24 diametral pitch, of steel or cast iron, and with round, square, or spline bore, either clean or copper plated. As the gears are used mostly on high-grade machine tools, the tooth surface and the running qualities of the gears must be maintained at a high standard. The speeds and feeds given in Tables XXXVII and XXXVIII were determined by experiment and were set to give this standard of quality. Number 12 Barber-Colman hobbers, such as that shown in Fig. 263, were used. The lot sizes of the gear blanks were small.

The following explanations concerning the several tables may make them more easily understood.

**Table XXXII—Handling Time—Machine Manipulation.** The time for machine manipulation will depend upon the way the gears are cut. Four different methods are shown. The time required to chuck and remove the gear (shown in Table XXXIII) is independent of the method of cutting.

**Table XXXIII—Handling Time—Chucking and Removing.** The data show that the time to chuck and remove the gears varies with the different types of bore, i.e., square, round, and spline, and also with the condition of the bore. When gears are casehardened it is frequently desirable to harden only the tooth surface. The blank, therefore, is copper plated before cutting in order that only the surface where the copper plating has been removed will be affected. Because of the copper plating on the bore, more time is required for chucking and removing, as this table shows.



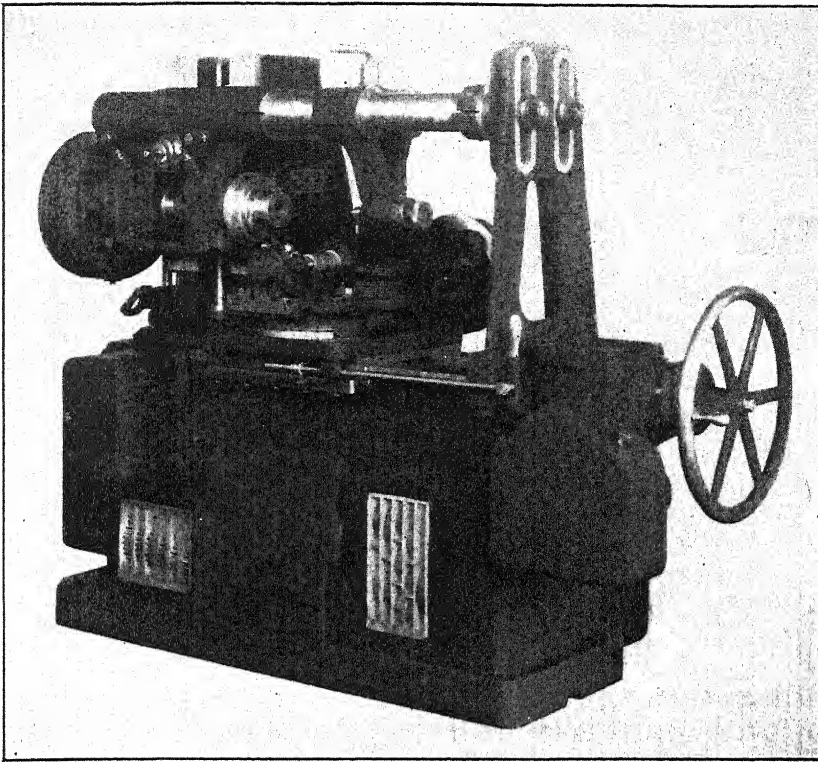


Fig. 263. Barber-Colman gear hobber.

## MACHINE DATA

Machine class—No. 53B  
 Manufacturer—Barber-Colman Co.  
 Used for—Spur gears, helical gears,  
 sprockets, splining

Type of machine—hobber  
 Serial Nos.—1053, 1178, 1544, 1551, 1576

## GENERAL SPECIFICATIONS

Capacity, diameter.....	12"	Taper hole in spindle.....	No. 12 B&S
Capacity, width of face.....	10"	Driving pulley.....	14" × 3 1/4"
Capacity, diametral pitch, cast iron	5	Speed of driving pulley.....	300-400 r.p.m.
Capacity, diametral pitch, steel....	6	Number of changes of hob speed.....	8
Diameter of hob spindle.....	1 1/4"	Hob speeds.....	.45 to 220 r.p.m.
Maximum diameter of hob.....	4"	Range of feed.....	.015" to .150"
Floor space.....	43" × 76"		
Net weight, approximately.....	4600 lb.		

**Table XXXVI—Overtravel Allowance.** The overtravel required for rough hobbing is determined in the same manner as for milling. It is affected by the diameter of the hob and the depth of the cut.<sup>1</sup>

The 1/8-inch overtravel allowance for finishing hobbing is sufficient for clearance at the beginning and at the end of the cut.

<sup>1</sup> M. A. Lee and D. Vandevate, "Time Setting in a Machine Tool Plant," *Industrial Management*, Vol. 69, No. 3, p. 152.



TABLE XXX  
SETUP TIME—STRAIGHT SPUR GEARS  
Time in Minutes

Elements	Rough and Finish with Same Hob	Rough with Rough Hob— Finish with Finish Hob
1. Ring clock, get drawing	2.00	2.00
2. Remove hob	0.60	0.60
3. Get hob and arbor from toolcrib	4.00	4.00
4. Place hob in machine	2.00	2.00
5. Set helix angle and check	1.00	1.00
6. Place and true-up arbor	6.00	6.00
7. Change index gearing	1.50	1.50
8. Check index gearing	2.65	2.65
9. Change speed gearing	0.75	0.75
10. Change feed gearing	1.50	1.50
11. Set for depth	0.75	0.75
12. Try for size (av. 3 trial cuts)	12.00	12.00
13. Ring clock	.....	2.00
14. Remove hob	.....	0.60
15. Place hob	.....	2.00
16. Set helix angle and check	.....	1.00
17. Change index gearing	.....	1.50
18. Change speed gearing	.....	0.75
19. Change feed gearing	.....	1.50
20. Set for depth	.....	0.75
21. Trial cuts (adjust index)	.....	5.00
Total Setup Time	35.00	50.00

### Cutting Time Formula

$$M = \frac{N \times L}{F \times S \times H}$$

where  $M$  = cutting time in minutes

$N$  = number of teeth

$L$  = total length of cut (length of face plus overtravel)

$F$  = feed in inches per revolution of work

$S$  = speed of hob in r.p.m.

$H$  = lead of hob

(a) single = 1

(b) double = 2



TABLE XXXI

## HOB CHANGE TIME—STRAIGHT SPUR GEARS

Time in Minutes

1. Remove hob	0.60
2. Place hob in machine	2.00
3. Set helix angle and check	1.00
4. Change index gearing	1.50
5. Check index gearing	2.65
6. Change speed gearing	0.75
7. Change feed gearing	1.50
8. Make trial cuts	5.00

---

 Total Hob Change Time 15.00

Hobbing is a continuous cutting action from the start to the finish of the travel of the hob across the entire gear face. One revolution of the work advances the hob a distance equal to the feed.

$$(1) \frac{N \text{ (number of teeth)}}{H \text{ (lead of hob)}} = \text{revolutions of hob per revolution of work}$$

$$(2) \frac{\frac{N}{H} \text{ (revolutions of hob per revolution of work)}}{S \text{ (speed of hob in r.p.m.)}} = \text{time in minutes per revolution of work}$$

$$(3) \text{ Since: } \frac{L \text{ (the total length of face)}}{F \text{ (feed in inches per revolution of work)}} = \text{number of revolutions of work required}$$

(4) Then:

$$M = \frac{N}{H} \times \frac{L}{F} = \frac{N \times L}{F \times S \times H}$$

*Example.* In order to show how the data and formula are applied, the time required to hob a gear will be determined. It will be assumed that an order has been received for 20 Feed-Change Gears as shown in Fig. 264. The procedure is as follows:

1. The following necessary data are taken from the drawing of the gear (Fig. 264): Length of face = 1 inch, diametral pitch (D.P.) = 10, number of teeth ( $N$ ) = 60, spline bore, S.A.E. 2315, hob S10R, plain spur gear.



TABLE XXXII  
HANDLING TIME—STRAIGHT SPUR GEARS  
Time in Minutes

## A. Machine Manipulation

Procedure	Rough and Finish S. L. Hob		Rough with Rough Hob. Finish with Finish Hob.	Rough and Finish in One Cut.
	With Feed Change	No Feed Change		
1. Walk to machine.....	0.20	0.20	0.20	0.20
2. Run carriage back.....	0.15	0.15	0.15	0.15
3. Loosen arbor nut.....	0.09	0.09	0.09	0.09
4. Loosen and back steady rest.	0.08	0.08	0.08	0.08
5. Remove arbor nut.....	0.12	0.12	0.12	0.12
6. Remove gears.....	*	*	*	*
7. Chuck blanks.....	*	*	*	*
8. Set nut on arbor.....	0.20	0.20	0.20	0.20
9. Advance arbor steady rest..	0.12	0.12	0.12	0.12
10. Tighten nut on arbor.....	0.10	0.10	0.10	0.10
11. Loosen overarm nut.....	0.06	0.06	....	....
12. Loosen 4 nuts on upright....	0.14	0.14	....	....
13. Set depth.....	0.15	0.15	....	....
14. Tighten 4 nuts on upright....	0.15	0.15	....	....
15. Tighten overarm nut.....	0.11	0.11	....	....
16. Change feed gearing.....	1.50	....	....	....
17. Start machine.....	0.08	0.08	0.08	0.08
18. Feed in by hand.....	0.10	0.10	0.10	0.10
19. ROUGH CUT.....	M	M	M	M
20. Walk to machine.....	0.20	0.20	0.20	....
21. Run carriage back.....	0.15	0.15	0.15	....
22. Loosen arbor nut.....	....	....	0.09	....
23. Loosen and back steady rest.	....	....	0.08	....
24. Centerpunch gears.....	....	....	0.33	....
25. Remove arbor nut.....	....	....	0.12	....
26. Remove gears.....	....	....	*	....
27. Chuck gears and lineup....	....	....	0.20	....
28. Set nut on arbor.....	....	....	0.20	....
29. Advance arbor steady rest....	....	....	0.12	....
30. Tighten nut on arbor.....	....	....	0.10	....
31. Loosen overarm nut.....	0.06	0.06	....	....
32. Loosen 4 nuts on upright....	0.14	0.14	....	....
33. Set depth.....	0.15	0.15	....	....
34. Tighten 4 nuts on upright....	0.15	0.15	....	....
35. Tighten overarm nut.....	0.11	0.11	....	....
36. Change feed gearing.....	1.50	....	....	....
37. Advance hob and set index..	....	....	1.00	....
38. Start machine.....	0.08	0.08	0.08	....
39. Feed in by hand.....	0.10	0.10	0.05	....
40. FINISH CUT.....	M	M	M	....
Hob change allowance.....	0.30	0.30	0.30	0.30
Total handling time per chucking	6.29	3.29	4.26	1.54
“ “ “ —roughing..			1.90	
“ “ “ —finishing..			2.36	

\* See Table XXXIII.

Note: When speed gearing must be changed between cuts add 1.50 minutes to total handling time.



2. Method of Cutting—from Table XXXIV. Use single lead hob on roughing and on finishing. Take a rough cut and a finish cut.
3. Setup Time—from Table XXX. Setup time = 35.00 minutes.
4. Number of Gears per Chucking—from Table XXXV.  
(4) Gears without hubs, 1-inch face or over, 3 per chucking.
5. Outside Diameter of Hob—from Table XXXIX. Hob S10R = 2.756 inches

TABLE XXXIII

## HANDLING TIME

## B. Chucking and Removing

Time in Minutes

Bore	Chucking			Removing
	First Gear	Second Gear	Each Additional Gear	Any Number
1. Square bore—clean	0.08	0.03	0.08	0.10
2. Square bore—copper-plated	0.25	0.20	0.15	0.25
3. Round bore—clean	0.10	0.10	0.10	0.10
4. Round bore—copper-plated	0.25	0.20	0.15	0.25
5. Spline bore	0.10	0.03	0.08	0.20

TABLE XXXIV

## METHOD OF CUTTING

Diametral Pitch	Material		
	Steel		Cast Iron
	Roughing	Finishing	Finishing
Over 16	....	S.L.	All pitches one cut
16 and under	S.L.	S.L.	S.L.
Except 4	D.L.	S.L.	S.L.

S.L. = Single Lead Hob. D.L. = Double Lead Hob.



TABLE XXXV

## NUMBER OF GEARS PER CHUCKING

## A. Gears without Hubs

Width of Face	Number per Chucking
1 in. or over	3
$1\frac{3}{16}$ in. to 1 in.	4
$\frac{5}{8}$ in. to $\frac{3}{4}$ in.	5
$\frac{1}{2}$ in. to $\frac{5}{8}$ in.	6
Under $\frac{1}{2}$ in.	7 or more

## B. Gears with Hubs

1. When the hub projection is  $\frac{1}{8}$  in. or less, add hub projection to width of face and use Table XXXVA above.
2. When the hub projection is greater than  $\frac{1}{8}$  in., chuck not more than two blanks at one time.

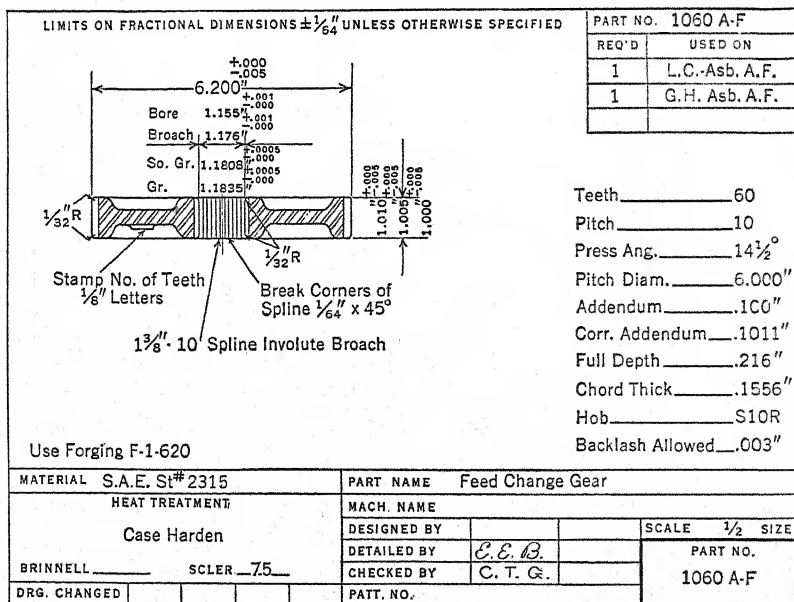


FIG. 264. Detail drawing of a change gear, part 1060A-F.



6. Speed of Hob—from Table XXXVII. For hob with O.D. of 2.756 inches, S.A.E. 2315, speed = 138 r.p.m.
7. Feed—from Table XXXVIII. For D.P. = 10, steel, ground hob, S.L., rough and finish, feed = 0.050 inch per revolution.
8. Overtravel—from Table XXXVI.
  - (A) Roughing, D.P. = 10, O.D. of Hob =  $2\frac{3}{4}$  inches, overtravel = 0.74 inch.
  - (B) Finishing = 0.125 inch.

TABLE XXXVI  
OVERTRAVEL ALLOWANCE  
A. Roughing

D.P.	Full Depth in Inches	Overtravel in Inches *							
		Outside Diameter of Hob in Inches							
		2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	4	5
24	0.090	0.42	0.44	0.47	0.49	0.51	0.55	....	....
20	0.108	0.45	0.48	0.51	0.54	0.56	0.61	....	....
16	0.135	0.50	0.53	0.57	0.59	0.62	0.67	....	....
14	0.154	0.53	0.57	0.60	0.63	0.66	0.72	....	....
12	0.180	0.57	0.61	0.65	0.68	0.71	0.77	0.83	....
10	0.216	0.62	0.66	0.70	0.74	0.78	0.85	0.90	1.02
8	0.270	....	0.73	0.78	0.82	0.86	0.93	1.00	1.13
7	0.301	....	....	0.82	0.86	0.90	0.98	1.06	1.19
6	0.360	....	....	....	0.93	0.97	1.06	1.15	1.29
5	0.432	....	....	....	....	1.05	1.15	1.24	1.40
4	0.540	....	....	....	....	1.15	1.26	1.37	1.55

\* Derived from formula  $O = \sqrt{h(2r - h)}$

where  $O$  = overtravel

$h$  = full depth of gear tooth

$r$  = radius of hob

B. Finishing—0.125 inch Overtravel Allowed

9. Calculation of Cutting Time—from formula on page 406.

	<i>Roughing</i>	<i>Finishing</i>
$M = \frac{N \times L}{F \times S \times H}$	$N = 60$	60
	$L = (3 + .74)$	$(3 + 0.125)$
	$F = 0.050$	0.050
	$S = 138$	138
	$H = 1$	1



TABLE XXXVII

## SPEED TABLE

Speed of Hob in Revolutions per Minute

Outside Diameter of Hob in Inches	Cast Iron	Rough (Single Lead) S.A.E. 2315	Rough and Finish S.A.E. 2315	Rough and Finish S.A.E. 1035	Rough and Finish S.A.E. 1020
	Rough (Double Lead) S.A.E. 2315		Rough Only S.A.E. 1035	Finish Only S.A.E. 2315	Finish Only* S.A.E. 1035 S.A.E. 1020
				Rough Only S.A.E. 1020	
	Cutter Speed Feet per Minute				
	90	100	110	125	140
2.00	161	189	189	189	189
2.20	161	189	189	189	189
2.40	138	161	189	189	189
2.50	138	161	161	189	189
2.60	138	138	161	189	189
2.75	120	138	138	161	189
2.90	120	138	138	161	189
3.00	110	120	138	161	189
3.10	110	120	138	161	189
3.25	110	120	138	138	161
3.40	110	110	120	138	161
3.50	110	110	120	138	161
3.75	82	110	110	120	161
4.00	82	82	110	120	138
4.25	82	82	82	110	138
4.50	76	82	82	110	120

Roughing:

$$M = \frac{60 \times (3 + 0.74)}{0.050 \times 138 \times 1} = 32.5$$

Finishing:

$$M = \frac{60 \times (3 + 0.125)}{0.050 \times 138 \times 1} = 27.2$$

$$\text{Total cutting time} = 32.5 + 27.2 = 59.7 \text{ minutes}$$

## 10. Determination of Total Handling Time.

(A) Machine Manipulation—from Table XXXII, column 2 (no feed change)  
= 3.29 minutes.



TABLE XXXVIII

## FEED TABLE

Feed in Inches per Revolution of Work

Material	Steel				C.I.
Cut	Roughing	Roughing	Rough and Finish	Finishing	Rough and Finish
Lead of Hob	Single or Double	Single or Double	Single	Single	Single
Kind of Hob	Form	Ground	Ground	Ground	Ground
Dia. Pitch					
24	.....	.....	0.050	0.050	0.090
20	.....	.....	0.050	0.050	0.0875
16	.....	.....	0.050	0.050	0.0875
14	.....	.....	0.050	0.050	0.0834
12	.....	.....	0.050	0.050	0.0834
10	0.070	0.125	0.050	0.050	0.070
9	0.070	0.125	0.050	0.050	0.070
8	0.070	0.125	0.050	0.050	0.070
7	0.070	0.1125	0.045	0.045	0.0643
6	0.070	0.100	0.045	0.045	0.0643
5	0.0643	0.09375	0.041	0.041	0.0643
4	0.060	0.090	0.041	0.041	0.060

Feed changes between cuts are practicable only when the cuts are exceptionally long, and the change will make an appreciable net saving of time.

(B) Chucking and Removing—from Table XXXIII, spline, three blanks, chucking = 0.26 minute, removing = 0.20, total = 0.46 minute.

Total handling time =  $3.29 + 0.46 = 3.75$  minutes.

11. Determination of Total Standard Time.

Total handling time for three gears = 3.75

Total cutting time for three gears = 59.7

Total normal time for three gears = 63.45

5 per cent allowance = 3.17

Total standard time for three pieces = 66.62

Total time for one piece =  $\frac{66.62}{3} = 22.2$  minutes



TABLE XXXIX

HOB LIST

Hob No.	Hob O.D.	Hob No.	Hob O.D.	Hob No.	Hob O.D.	Hob No.	Hob O.D.
S24R	2.484	R277R	3.509	S8-10R	2.746	S5RD	3.210
S20R	2.502	S10R	2.756	S8-10L	3.006	S5R	3.989
S16-21R	3.529	S10RD	2.691	S7-R	2.934	S5L	3.989
S16R	2.407	S10-12R	2.738	4MR	3.028	R68R	3.367
S16RD	2.518	S9R	2.331	S6RD	3.594	R76L	4.063
S14R	2.500	R37R	2.315	S6R	3.381	S4RD	
S13R	2.933	R38L	2.393	S6L	3.251	S4R	4.501
S12R	2.749	S8RD		S6-8R	3.014	S4L	3.695
S12L	2.848	S8R	2.974	S6RD	3.210	S4R-20°	3.913
S11R	2.162	S8L	2.974	R555L	3.915		

#### TIME STANDARDS FOR SOLDERING SIDE SEAMS ON BODY OF CAN

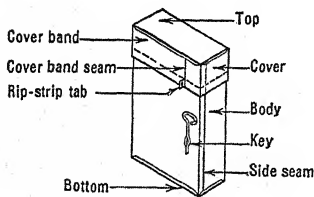


FIG. 265. Rectangular can for export shipment of instruments.

Rectangular cans similar in shape to the one shown in Fig. 265 are made for export shipment of drawing and surgical instruments. Lot sizes are usually small, and sixty different can sizes ranging in volume from a few cubic inches to one cubic foot are made. The total production of cans of any one size is not large enough to justify special can-making equipment.

#### Operations in the Manufacture of Cans

##### On Body:

1. Cut or slit body to length and width.
2. Make 4 breaks on the bar folder.
3. Solder the side seam.

##### On Cover:

1. Cut or slit cover band to length and width.
2. Punch hole in rip-strip tab.
3. Mark and make cut for loose end of the rip-strip and fold tab back 90 degrees.
4. Make first break on bar folder.



On Tops and Bottoms:

1. Cut to length and width.
2. Miter four corners.
3. Fold four sides.

Assembly:

1. Form cover band to body and solder band seam.
2. Solder the top to the cover, solder the bottom to the body, and then solder rip-strip key to the body.
3. Inspect, wash, and dry.

Since it is the primary purpose of this case to illustrate the application of principles, only one of the operations listed above will be considered in detail here. It is: "Solder the side seam of the body."

**Determination of Standard Time for "Solder the Side Seam of the Body."** It was found most satisfactory to use stop-watch studies for securing all the data except those for the "soldering" element. Micromotion studies were used for that element.

### Definition of Standard Elements for Soldering the Side Seam

1. Position piece on rod and apply the flux to the seam.

The time begins as the last finished can is released by the hand to a tote box.

The time ends as the hand completes the application of the flux and starts to move toward the soldering iron in the furnace.

2. Tack<sup>2</sup> the seam and then pick up the holder and position it on the can so as to hold the seam tightly together.

The time begins as the hand starts toward the soldering iron from the preceding element.

The time ends as the hand again starts toward the soldering iron in the furnace after positioning holder.

3. Solder the full length of the seam.

The time begins as the hand starts toward the soldering iron in the furnace.

The time ends as the hand releases the iron after disposing of it in the furnace.

4. Wipe the seam with a damp cloth and dispose.

The time begins as the iron is released upon disposal in the furnace.

The time ends as the hand releases the can into the tote box.

<sup>2</sup> "Tack" refers to placing a drop of solder on the seam to hold it in the correct position while it is being soldered. A long seam requires that more points be tacked than does a short seam.

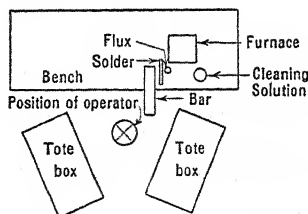


FIG. 266. Layout of work place for soldering rectangular cans.



## Standard Time for Elements

<i>Elements</i>	<i>Time Standard in Minutes per 100 Cans</i>
1. Position piece on rod and apply the flux to seam This element is a constant for cans of all sizes.	14.0
2. Tack the seam and then pick up the holder and position it on the can to hold the seam tightly together.	
(a) Untacked (seams under 3 inches in length)	0
(b) Two tacks per seam (seams 3.1 inches to 12 inches long)	16.0
(c) Three tacks per seam (seams 12.1 inches to 24 inches long)	23.0

If the seam is under 3 inches in length this element is not required. If the seam is between 3.1 inches and 12 inches in length it must be tacked at two places and clamped with a special holder before soldering. If between 12.1 inches and 24 inches long the seam must be tacked at three points and clamped. Time standards were determined by stop-watch studies.

## 3. Solder the full length of the seam.

The operator grasps the soldering iron, dips it in the pot of cleaning solution, touches it against the bar of solder, and moves it to the seam and draws the tip of the iron along the seam, soldering it until the supply of solder on the iron is used up. The iron is then returned to the bar of solder for a new supply and the soldering operation is repeated. If the seam has been tacked, fewer contacts of the iron against the bar of solder will be needed.

- (a) Grasp iron, dip in cleaning pot and dispose of iron to furnace = 0.08 minute, a constant per seam or series of seams. (From micromotion study.)  
(b) Solder seam.

From a micromotion study of soldering seams of various lengths it was found that there was a straight line relationship between the time in minutes to solder a seam and the length of the seam in inches. (See equations at the top of page 417.)

TABLE XL

( $N$  = Number of dips of iron against solder per seam)

Value of $N$	Seam Lengths in Inches	
	Untacked	Tacked
1	0-6.0	0-10.0
2	6.1-12.0	10.1-20.0
3	12.1-18.0	20.1-30.1
4	18.1-24.0	
5	24.1-30.0	

(From stop-watch studies and micromotion studies)



Time for soldering =  $L \times 0.014$

( $L$  = length of seam to be soldered in inches.)

(c) Touch iron to solder and move to seam =  $N \times 0.04$  minute.

$N$  = the number of dips necessary for seam. Table XL.

4. Wipe the seam with a damp cloth and dispose = 10.0 minutes per 100 cans—a constant for cans of all sizes.

### Auxiliary Elements

5. Handling of empty and full tote boxes. This time varies with the size of the can.

Handling time for the cans =  $P \times 0.0009$  minute. ( $P$  = the sum of the length, width, and depth of the can in inches.) From all-day stop-watch studies.

6. Filing, forging, and retinning soldering irons require 22 minutes per 480-minute day, or 4.6 per cent of the day. From all-day stop-watch studies.

### The Sum of All Constant Elements

	<i>Time Standard in Minutes per 100 Cans</i>
1. Position piece on rod and apply flux to the seam	14.0
2. Tack seam and then pick up the holder and position it on the can	
(a)	0.0
(b)	16.0
(c)	23.0
3. Wipe the seam with a damp cloth and dispose	10.0

### Formula for Determining Time Standard

$$\begin{aligned}
 \left[ \begin{array}{c} \text{Standard Time} \\ \text{in Minutes per} \\ \text{100 Cans} \end{array} \right] &= 100 \left\{ \left[ \begin{array}{c} \text{Time for} \\ \text{Constant} \\ \text{Elements} \end{array} \right] + \left[ \begin{array}{c} \text{Time for} \\ \text{Solder-} \\ \text{ing} \end{array} \right] + \left[ \begin{array}{c} \text{Time for} \\ \text{Handling} \\ \text{Can} \end{array} \right] \right\} + \left[ \begin{array}{c} \text{Time for} \\ \text{Maintain-} \\ \text{ing Iron} \end{array} \right] \\
 &= 100 \left\{ D + [0.08 + (L \times 0.014) + (N \times 0.04)] + [P \times 0.0009] \right\} \\
 &\quad + 4.6 \left\{ D + [0.08 + (L \times 0.014) + (N \times 0.04)] + [P \times 0.0009] \right\} \\
 &= 104.6 \left\{ D + [0.08 + (L \times 0.014) + (N \times 0.04)] + [P \times 0.0009] \right\}
 \end{aligned}$$

TABLE XLI

( $D$  = The sum of all constant elements)

Values of $D$ in Min. per Can	Seam Lengths in Inches	No. of Tacks
0.24	under 3.0	0
0.40	3.0–12.0	2
0.47	12.1–24.0	3



where  $L$  = the length of the seam to be soldered in inches

$N$  = the number of dips necessary to complete the seam (from Table XL)

$P$  = the sum of the length, width, and depth of the can in inches

$D$  = the sum of all constants (from Table XLI)

### Application of the Formula

Can 439 has the following dimensions: length,  $8\frac{5}{8}$  inches; width,  $\frac{3}{4}$  inch; depth,  $10\frac{1}{8}$  inches.

Values of above terms are:  $L = 10.125$ ;  $N = 2.0$ ;  $P = 19.5$ ;  $D = 0.40$ .

Substituting these values in the formula, we have

$$\begin{aligned}\text{Std.} &= 104.6\{0.40 + 0.08 + (10.125 \times 0.014) + (2 \times 0.04) + 19.5 \times 0.0009\} \\ &= 104.6(0.40 + 0.08 + 0.142 + 0.08 + 0.0176) \\ &= 104.6 \times 0.7196 = 75.27. \text{ Use 75.3 minutes.}\end{aligned}$$

Although the method of setting up a formula for determining the time standard for soldering the side seam has been presented in some detail, it is not necessary to go through this rather long procedure for each new lot or for each new can size. This formula applies to the operation "solder side seam" for all rectangular cans of any size falling within the range of the studies. In fact, it is not even necessary to use the formula, for tables have been constructed from computations made with the formula, and from these tables it is a very simple matter to determine the time standard for soldering operations on a can of any size. These tables are as easy to use as the mileage chart on a road map.

**Results.** Before standardizing the arrangement of the work place and the method of making the cans, all time standards were set by individual stop-watch studies. Since only a few can sizes had been studied, most of this work was not on wage incentive.

After the completion of the standardization program and the computation of the tables for setting time standards, it was possible to determine quickly the time standard for the soldering operations on a can of any size.

Decrease in labor costs resulting from improved methods and from the application of time standards and wage incentives to soldering operations in can making brought about a saving of approximately 4000 man-hours of direct labor per year. A total of 510 hours were spent by the analyst in completing the motion and time study work on this project.



## CHAPTER 25

### DETERMINING TIME STANDARDS FOR DIE AND TOOL WORK

Tool-room work is one of the most difficult of all industrial operations to standardize and place on wage incentive. It is true because the making of tools and dies requires a high degree of accuracy and the work is nonrepetitive since rarely is more than one tool of a given design required. Highly skilled die makers are required for this work, and on some operations a considerable amount of hand filing, scraping, and fitting may be required along with the machine work. Although it may seem that no two tools are alike, all tools of a given class have similar parts, and each part requires similar operations for its manufacture. The variation in the time required for the same operation on similar parts is due to different characteristics of the particular part, such as its size and the kind of material. It is possible here, as it was in the several cases in preceding chapters, to separate each operation into those elements that remain constant and those elements that vary with the size, shape, or other characteristic of the part.

The material to be presented in this chapter is taken from an outstanding piece of work done by Floyd R. Spencer in standardizing the die and tool work in a large industrial plant. This included compiling elemental time data and constructing charts and formulas for determining time standards. Using these standards, a wage-incentive system was installed which materially reduced the cost of this work. The tool makers had confidence in this method of setting time standards and believed it to be far superior to the rather crude method of "estimating" time on such work, as practiced in most tool rooms. The incentive plan based on these time standards permits the tool makers to earn substantially more wages than formerly.

The time required to determine the standard time by means of charts, curves, and formulas is one-fourth to one-half that required for estimating as formerly. For example, it takes 3 to 5 minutes to set the time standards for all operations required in making the plain blanking die shown in Figs. 267 and 268, whereas it would take



10 to 15 minutes to "estimate" the time by the old procedure. One person now determines time standards for a department employing 125 tool makers, whereas in most shops one estimator is needed for every 30 tool makers employed.

**Types of Dies.** The various types of dies for which standard data are now available are:

1. Plain Blanking.
2. Compound Blank and Perforate.
3. Single and Multiple Perforator.
4. Shearing.
5. Blank and Draw.
6. Forming.
7. Miscellaneous.

**Plain Blanking Dies.** The plain blanking die (such as the one shown in Fig. 267) will be used as an illustration because of its simplicity and general use. An explanation will be given of the method used in classifying all blanking work, the way the elemental time data, charts, and formulas were established, and finally a specific case will be given to show how the standard time is established for making a particular die.

The tool room for which these data apply normally employs 125 tool makers and serves a manufacturing plant employing 4000 to 5000 workers. The products manufactured are widely diversified in kind and are fairly small in size.

The first step in establishing a method for setting time standards on making blanking dies was to classify all blanks that would normally be manufactured by this type of die. A survey of all such work led to the following general classification:

1. Round blanks.
2. Square or rectangular blanks.
3. All blanks of other shapes.

Under the general classifications of pieces with round outlines and those with square or rectangular outlines a further classification must be made of projections or indentations. It is generally advisable to use inserts for projections or indentations on the piece in question. These inserts would be used in the pad and punch (see Figs. 267 and 268) for projections and in the die block for indentations. The inserts are used because of the low repair cost in breakage of these projections. A complete classification of blanks is given in Table XLII.



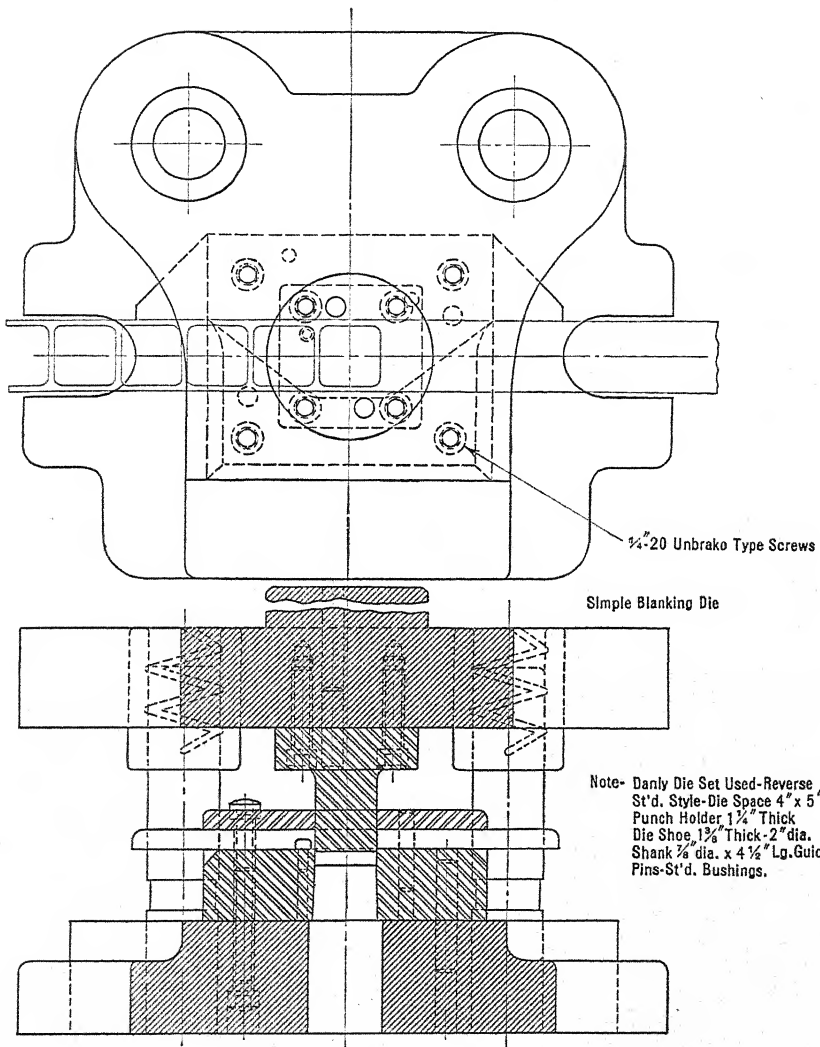
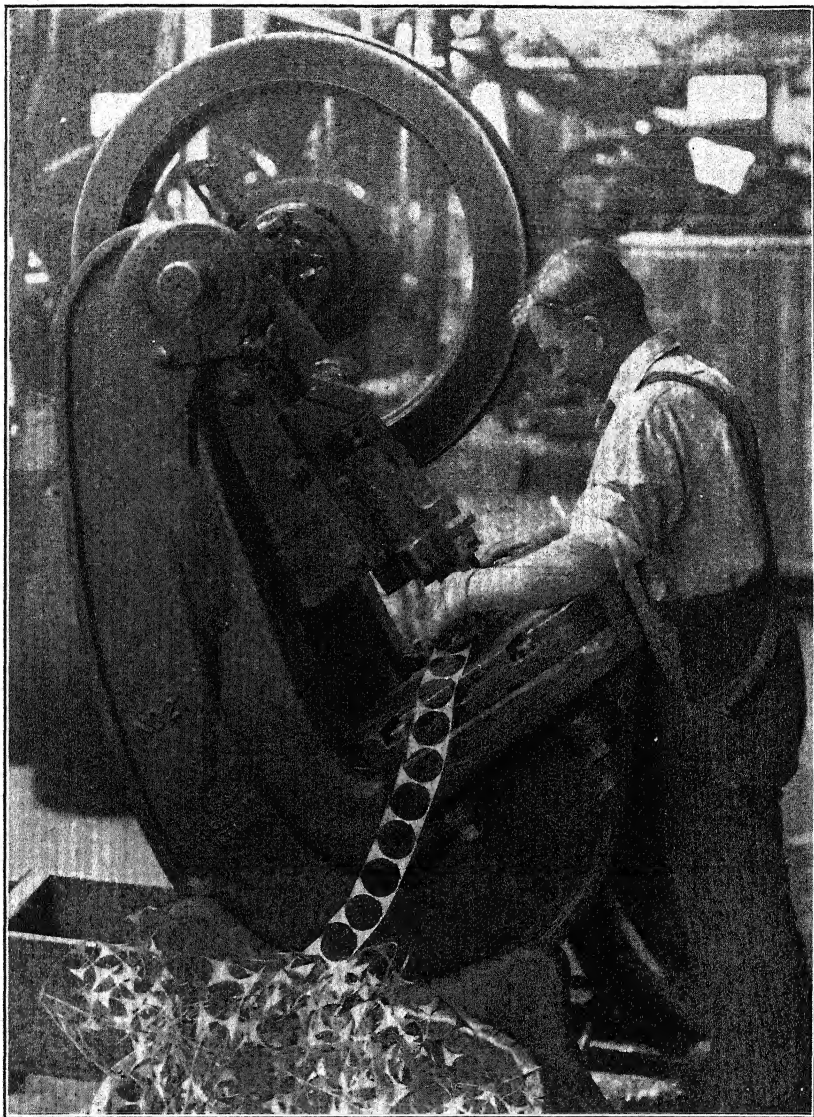


FIG. 267. Plain blanking die.











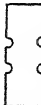







*Courtesy of E. W. Bliss Co.*

FIG. 269. Inclined punch press, No. 21 Bliss. This photograph shows an operator blanking, forming, and piercing bicycle bell bases at the rate of 1300 per hour. The material is cold rolled steel, 0.035-inch stock.



TABLE XLIII  
CLASSIFICATION OF WORK DONE ON PLAIN BLANKING DIES

Classifi- cation	No. 1	No. 2	No. 3
Shape of Blank	Round blanks	Square or rectangular blanks	All blanks of other shapes
	<p>Round.....</p> <p>Round with inden- tations.....</p> <p>Round with projec- tions.....</p>	<p>Plain outline.....</p> <p>With indentations </p> <p>With projections.. </p>	<p>(a) Blanks whose out- line is made up of smooth curves and straight lines or a combination of the first two classifications.  </p> <p>(b) Blanks whose outline is very irregular, having no simi- larity with blanks of round or straight-sided outline.  </p>
Size of blank	1/2-in. diam. to 4 in. diam.	3/8 x 1 1/2 in. to 5 1/2 x 7 in.	Same range as in classifications No. 1 and 2



It is customary to purchase the die sets from manufacturers specializing in making these parts. The die set consists of two parts as Figs. 267 and 268 show, namely the punch holder, part 1A, and the die shoe, part 1B. The classification of die sets is given in Table XLIII.

TABLE XLIII  
PURCHASED DIE SETS CLASSIFIED BY SIZE RANGE  
Size in Inches

Symbol	B1	B2	B3	B4	B5	B6	B7	B8
Maximum size round blank	1 $\frac{3}{8}$	1 $\frac{7}{8}$	2 $\frac{3}{8}$	3 $\frac{1}{8}$	3 $\frac{7}{8}$	4 $\frac{1}{4}$	5	6
Maximum size rectangular blank	$\frac{3}{8} \times 1\frac{1}{2}$	$1\frac{1}{2} \times 2$	$1\frac{1}{8} \times 2\frac{3}{8}$	$2\frac{1}{4} \times 3\frac{1}{4}$	$3 \times 4$	$4\frac{1}{4} \times 4\frac{1}{4}$	$4\frac{1}{2} \times 7$	$5\frac{1}{2} \times 7$

**Parts of a Blanking Die.** The principle of a plain blanking die is very simple. The strip of sheet metal stock to be blanked is fed in the die from right to left as shown in Fig. 267. The punch, which is the shape of the blank to be made, is moved downward by the action of the press (see Fig. 269) and punches a piece from the stock, the blank being forced through the die block by the punch. The stripper removes the stock from the punch as it returns to its normal position.

Figure 267 shows an assembly drawing of a plain blanking die, and Fig. 268 shows the component parts of this die. A list of all the parts of this die is given here:

- |    |                                  |                       |
|----|----------------------------------|-----------------------|
| 1A | Punch Holder                     | } Die Set (purchased) |
| 1B | Die Shoe                         |                       |
| 2  | Punch                            |                       |
| 3  | Stripper                         |                       |
| 4  | Stock Guide                      |                       |
| 5  | Die Block                        |                       |
| 6  | Stock Stop Pin (a standard part) |                       |

**Operations on Punch Holder—Part 1A.** Although the die sets, composed of punch holder and die shoe, were purchased from an outside source, the following operations were performed on these parts:

- Operation 1 Set up mill, mill stem to height  
 Operation 2 Lay out, drill and tap for screw holes, drill and ream for dowels



The next step was to determine the variables or the basic factors that governed the time required for each operation and the percentage of the extent of total time that each factor controlled.

		<i>Percentage</i>
Operation 1	Size and weight of punch holder	100
Operation 2	Number of screw and dowel holes	85
	Size and weight of punch holder	15

In the tool room actual studies were made of the operations required to machine the punch holder. Data were taken for many different sizes and weights and finally, after being checked and tested for accuracy, these data were compiled in tabular form for convenient use as shown in Tables XLIV and XLV.

**Operations on Die Block—Part 5.** The die block is perhaps the most important part of the tool and it must be made accurately in order to produce blanks to meet production requirements. In determining time standards for making the die block the following procedure was used:

1. A list was made of all variables or governing factors that would in any way affect the time required to make the die block. They were:
  - a. Length of outline of blank.
  - b. Number of inside angles.
  - c. Number of sides (0.250 inch in length or over).
  - d. Number of radii.
  - e. Curves on blank whose center is outside of blank.
  - f. Specifications of stock to be blanked.
2. A list was made of the operations which the tool maker must perform to make the die block, and the factors which have a bearing on the time required were noted. (See Table XLVI.)
3. Time standards were determined for each operation over the entire range of the governing factors. This was a much more difficult task than determining time standards for making the punch holder because so many more variables entered into making the die block. Approximately 100 die blocks of every conceivable shape were studied, and a considerable period of time was required for securing and classifying these data, and for establishing correct relationships.

**Curves for Setting Time Standard for Operation 4.** Of the seven operations required to make the die block, perhaps the most interest-



TABLE XLIV  
GOVERNING FACTOR—SIZE OF DIE SET REQUIRED TO BLANK PART  
Time in Hours

Operation No.	Percentage of Time Controlled by Factor	Symbol of Purchased Die Set Sizes							
		B1	B2	B3	B4	B5	B6	B7	B8
1	100	0.70	0.75	0.78	0.80	0.88	0.96	1.08	1.22
2	15	0.10	0.15	0.21	0.27	0.32	0.39	0.44	0.50

TABLE XLV  
GOVERNING FACTOR—NUMBER OF SCREWS AND DOWELS  
Time in Hours

Operation No.	Percentage of Time Controlled by Factor	3 Screws 2 Dowels	4 Screws 2 Dowels	6 Screws 2 Dowels	8 Screws 3 Dowels	12 Screws 4 Dowels	14 Screws 6 Dowels	18 Screws 8 Dowels	20 Screws 10 Dowels
		0.50	0.65	0.85	1.10	1.39	1.70	2.10	2.30
2	85								



TABLE XLVI

OPERATIONS AND GOVERNING FACTORS FOR DIE BLOCK—PART 5

Operation No.	Operation	Governing Factor
1	Cutoff	(a) Grade of material (b) Size of piece
2	Machine to size—Grind all over	(a) Grade of material (b) Size of piece
3	Layout shape on block surface	(a) Length of outline (b) Number of inside angles (c) Number of sides (d) Number of radii (e) Number of curves with centers outside blank
4	Work out shape through block	(a) Same factors as above—Operation 3
5	Drill and tap screw holes, drill and ream dowel holes	(a) Number of screw and dowel holes (b) Size of holes
6	Harden	(a) Grade of material
7	Grind	(a) Grade of material (b) Size of piece

ing one for illustrative purposes is operation 4, "Work out shape through block." The five variables or factors which govern the time required for performing this operation are listed in Table XLVI. The curves in Fig. 270 show the relationship between the variables and the time required. These data are also given in Table XLVII.

*Example.* To determine the time required to perform operation 4, "Work out shape through die block," for the blank shown in Fig. 271 the procedure would be as follows:

		Curve (Fig. No.)	Standard Time in Hours
(a) Outline in inches <sup>1</sup>	10.75	270a	9.00
(b) Inside angles	4	270b	2.50
(c) Number of sides	12	270c	5.00
(d) Number of radii	6	270d	1.75
(e) Number of radii with centers outside	0	....	....
Total standard time in hours for operation	4	....	18.25

<sup>1</sup> The outline of irregular dies is determined by means of a map measure—a simple instrument reading distance directly in inches.



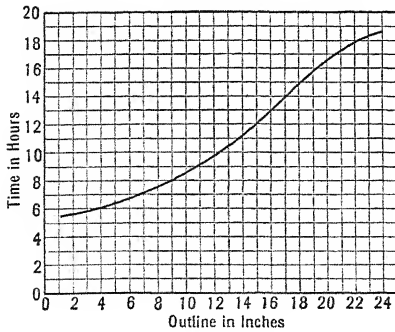


FIG. 270a  
PLAIN BLANKING DIE

Part 5.—Die Block.  
Op. 4.—Work out shape through block.  
Factor (a).—Length of outline of blank.

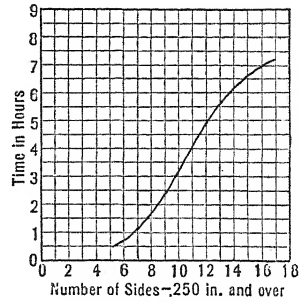


FIG. 270c  
PLAIN BLANKING DIE

Part 5.—Die Block.  
Op. 4.—Work out shape through block.  
Factor (c).—Number of sides.—0.250 in. or over.

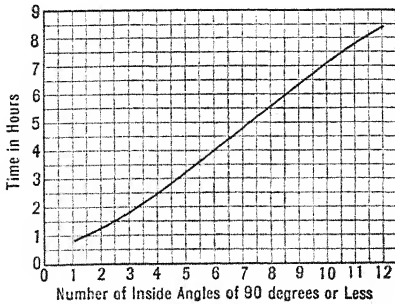


FIG. 270b  
PLAIN BLANKING DIE

Part 5.—Die Block.  
Op. 4.—Work out shape through block.  
Factor (b).—Number of inside angles of 90 degrees or less.

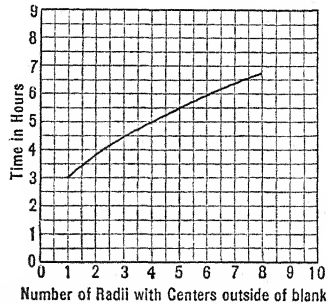


FIG. 270e  
PLAIN BLANKING DIE

Part 5.—Die Block.  
Op. 4.—Work out shape through block.  
Factor (e).—Number of curves with centers outside of blank.

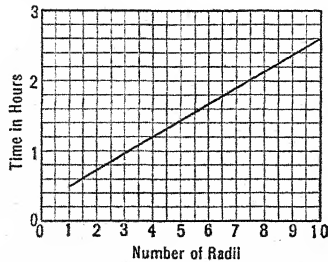


FIG. 270d  
PLAIN BLANKING DIE

Part 5.—Die Block.  
Op. 4.—Work out shape through block.  
Factor (d).—Number of radii.

FIG. 270. Curves for setting time standards for operation 4 on die block—plain blanking die.



TABLE XLVII

## STANDARD TIME FOR PERFORMING OPERATION 4

## WORK OUT SHAPE THROUGH DIE BLOCK

Time in Hours

(a) Outline in inches	1	3	6	10	12	14	18	20	24
Time	5.5	5.9	6.9	8.5	9.6	11.3	15.0	16.7	18.7
(b) Inside angles, 90° or less	1	2	3	4	5	6	8	10	12
Time	0.8	1.2	1.75	2.6	3.3	4.1	5.6	7.1	8.4
(c) Number of sides (length 0.250 inch and over)	5	6	7	8	9	10	12	14	16
Time	0.5	0.7	1.1	1.7	2.3	3.3	4.9	6.2	6.9
(d) Number of radii	1	2	3	4	5	6	8	10	
Time	0.5	0.7	0.9	1.2	1.4	1.7	2.1	2.6	
(e) Number of radii, centers outside	1	2	3	4	5	6	7	8	
Time	3.0	3.8	4.5	5.0	5.5	5.9	6.3	6.7	

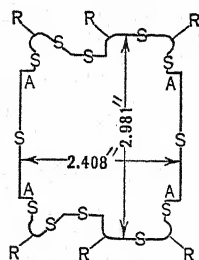


FIG. 271. Shape of blank. A. Inside angles; R. Radii; S. Sides.

The standard curves shown in Fig. 270 cover all possible combinations of contour and size affecting operation 4. Space does not permit the inclusion of the curves and data for the other operations on the die block. The same procedure was followed not only for the remaining operations on the die block but also for all operations on the other parts of the blanking die.

In a similar manner elemental data, charts, curves, and formulas were developed for the seven classes of dies listed on page 420.

**Quality Classification.** It is necessary to show how the quality of the tool enters into the determination of the time standard for making the die. The quality requirements for a die depend upon the following factors:



1. Appearance of the product.
2. Total production requirements of the product.
3. Use of the product.
4. Working action of the parts produced.
5. Cost factors of the products.

A study of the above factors resulted in the establishment of the following quality classification:

Class C—Reading from curves and charts—direct.

Class B—Reading from curves and charts multiplied by 112 per cent.

Class A—Reading from curves and charts multiplied by 130 per cent.

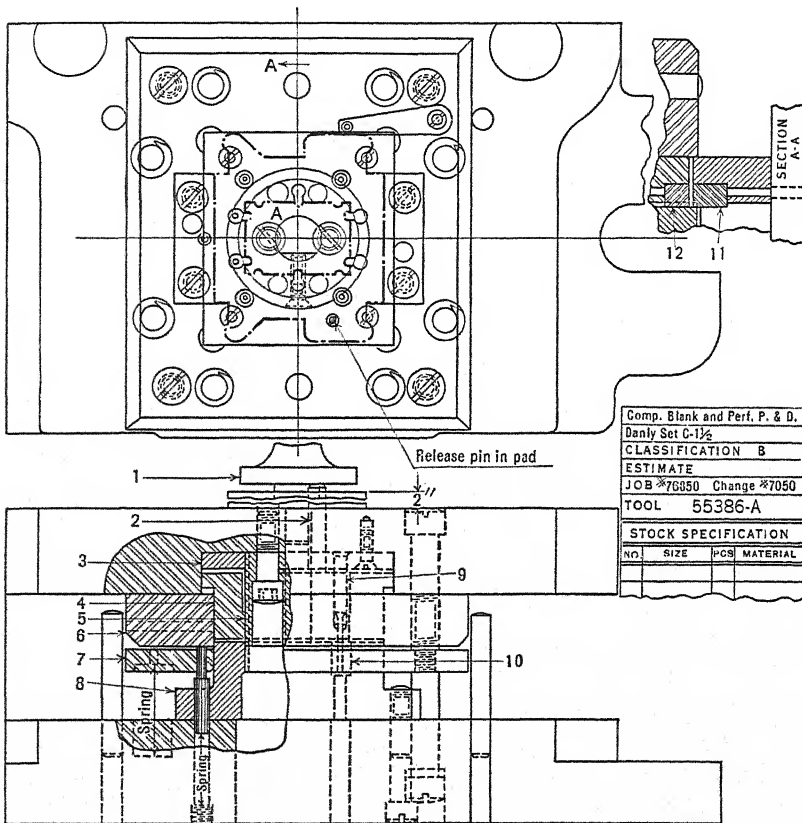


FIG. 272. Compound blank and perforate die.

The decision as to the classification of the various punches and dies is made before they are designed, and the classification is noted on the drawings when they are made.



TABLE XLVIII

## PUNCH AND DIE PARTS—BASE OF TIME-SETTING CURVES

## Compound Dies—Blank and Perforate—Class 2

## Blanks with Straight Sides or Smooth Curved Outline

Chart No.	Part of Punch and Die	Base of Chart (abscissa)
20-21-22	Pad—blank punch—stripper—punch plate	Outline in inches—Number of sides with angles 90° or less
5-7-13	Die shoe—punch holder—assembly work—hardening and miscellaneous	Size of die set
8	Perforators A. Round B. Square and rectangular C. Odd-shaped	A. Diameter of perforator B. Outline of perforator C. Outline of rough stock—Number of angles Outline of perforator—Length of slots
10	Placing round center holes through pad and punch—not center	Diameter of perforator
11	Placing square, square with indentations and projections, and odd-shaped holes through pad—punch—die shoe	Outline of perforator—Number of angles—Number of curves—Number of projections—Length of slot 0.125 wide and under
12	Bushings	Diameter of perforator—Number required
13	Minor curves	Number of curves requiring additional filing
13A	Inside radii	Number of radii requiring additional filing
14	Projections and indentations in blanking or perforating punch (with or without inserts)	Number of projections or indentations
14A	Projections and indentations (continued)	Length of outline for stock removed

**The Wage-Incentive Application.** Since punch-press parts usually require a series of operations for their manufacture, the several dies required to make a part completely are designed at one time. It is customary to design each tool in assembly, showing the construction of the tool, listing the material required, and indicating any special features but not showing the individual parts in detail. Time standards are then established by the method already described. The order



TABLE XLIX

CALCULATION OF STANDARD TIME FOR BLANK AND PERFORATE PUNCH AND DIE  
Compound Die Shown in Fig. 272

Chart Number	Information Required	Information Applicable to Die in Figure 272	Reading from Curves—Standard Time in Hours
20 and 21	Outline of blank	10¾	34
22	Number of sides	18	17¾
	Outside angles 90° or less	6	4¾
5-7-13	Size of die set	C11½	27½
	General outline	Square	
	Total number of perforations	5	1¼
8A	Number of perforators	4	2¼
	Diameter of perforators	0.068	
	Type—Perforator	Type B	
8B	Outline of perforator	5¼	5¾
	Number of perforators	1	
8C	Outline of stock from which blank is made		
	90° angles or less		
	Width up to 0.125 in.		
	Outline of perforator		
10	Number of perforators	4	6
	Diameter of perforators	0.068	
11A	Outline of perforator	5¼	9¼
	Number of projections on perforator punch	10	11
11B	Number of 90° angles or less		
	If form of slot 0.125 wide or less—Length		
12	Number of bushings	4	2½
	Size of inside diameter	0.068	
13	Number of minor curves		
13A	Number of radii	6	8½
14	Number of projections or indentations	10	50½
14A	Length of outline for stock removed		

Standard Time

180.75 hrs.

Quality Classification  $C = 180.75$ 

“ “  $B = 180.75 \times 112 = 202.44$ . Use 205 hours.



for the series of tools is then given to a group leader in the tool room to whom is assigned as many assistants as can do the job efficiently. These tool makers complete the entire series of tools for a given part as a group and share in the savings through a bonus which is based upon the difference between the time actually used and the time standard set for the job. At the completion of this series of tools the group dissolves, and new groups are formed for other tools.

**Compound Blank and Perforate Dies.** Compound blank and perforate dies are more complicated than plain blanking dies in that the compound dies have more parts. The method, however, for standardizing and establishing standard data for making these dies is exactly like that already described for the plain blanking die.

Space does not permit the presentation of similar material for compound dies. Table XLVIII, however, gives a list of the parts, and the summary in Table XLIX gives the standard time required to make complete the compound die shown in Fig. 272.

For additional information in this field, see C. N. Harwood, "Time Standards for the Drop Forge Die Shop," *Heat Treating and Forging*, Vol. 23, No. 11, pp. 549-555, November, 1937; also December, 1937, pp. 604-609; January, 1938, pp. 19-25; and February, 1938, pp. 65-70.



## CHAPTER 26

### DETERMINING TIME STANDARDS FOR ASSEMBLY OPERATIONS

#### CLASSIFICATION AND DEFINITION OF MOTIONS

#### DETERMINATION OF TIME VALUES

Elemental time values determined from stop-watch time studies are widely used for rate setting, and the process of establishing such time values is relatively simple, as has been described in the preceding chapters.

There is a trend toward the use of standard time values for therbligs or combinations of therbligs, and under certain conditions such time values may be more useful than the time values for longer elements obtained from stop-watch time studies.

The plan described in this and the following chapter was developed by Harold Engstrom and his associates while he was Motion Study Supervisor at the Bridgeport Plant of the General Electric Company. This material has been successfully used by this company for a number of years, first for estimating labor costs on new products, and more recently for establishing time standards. Other companies have adopted this plan and are also using it successfully for establishing time standards for wage incentives.<sup>1</sup>

Greatest success is obtained with this synthetic method of setting time values when a thorough analysis of a given kind of work is made,

<sup>1</sup> For motion-time data for punch press operations, see "Determining Time Standards for Strip Stock Punch Press Work," by Harold Engstrom, reprinted in *Motion and Time Study Applications*, by Ralph M. Barnes, published by John Wiley and Sons, New York, pp. 146-183; also H. C. Geppinger, "Planned Time Study Standards; General Electric Company," *The Iron Age*, Vol. 150, No. 18, pp. 34-6, Oct. 29, 1942. For motion-time data for such operations as hand screw machines, turret lathes, sensitive drills, and hand tappers, see "Development and Use of Standard Data," by Harold Engstrom, reprinted in "Work Measurement Manual," 3rd ed., pp. 156-192, 1947. Also see "Stop-Watch Time Study vs. Standard Data for Elemental Motions," by Ralph M. Barnes, *Modern Management*, Vol. 8, No. 4, July, 1948.



a suitable classification set up, and standard time values established for carefully defined motions or combinations of motions.<sup>2</sup>

In arriving at the classification of motions and the time values for each group the company (1) made extensive studies by means of motion pictures, (2) investigated operating conditions on the manufacturing floor, and (3) compared departmental time studies with motion-picture studies.

#### DERIVATION OF ASSEMBLY TIME STANDARDS

**Assembly Elements.** In an assembly operation a variety of parts are supplied to an operator who assembles them in definite positions. The operator must "*Get*" each part and "*Place*" it in proper position in relation to the rest of the assembly. When parts are fastened together, hand tools or machines may be "*Used*." Lastly, after completing an assembly cycle the device or assembly must be "*Placed Aside*" or "*Disposed*." All assembly operations are composed of a sequence of these elements. For practical purposes of analysis, it is unnecessary to reduce these four divisions to still smaller elements if the variables which affect them are recognized and properly evaluated.

**"Grasp" a Primary Variable.** Throughout any assembly operation, time is consumed in obtaining, maintaining, or releasing the control of parts, tools, or machines. In the assembly operations studied, this control was largely manual.

It was determined that the type of grasp used in controlling the part being assembled was perhaps the most important variable affecting get or place times. Although special features of design or relative difficulty of assembly may affect it, the type of grasp used is largely a function of the size of the part. Hence, for practical purposes, the size of parts may be used as one base for evaluating the variation of get or place times.

**Size of Part and Type of Grasp.** The size of parts is a satisfactory base for evaluating variations of get and place times when size is defined according to the type of grasp employed. It must be remem-

<sup>2</sup> For other systems of standard data for hand and body movements, see J. H. Quick, W. J. Shea, and R. E. Koehler, "Motion-Time Standards," *Factory Management and Maintenance*, Vol. 103, No. 5, pp. 97-108, May, 1945. Also M. G. Schaefer, "Establishing Time Values by Elementary Motion Analysis," *Proceedings of the Tenth Time and Motion Study Clinic, I.M.S.*, pp. 21-27, 1946; and "Development and Use of Time Values for Elemental Motions," *Proceedings of the Second Time Study and Methods Conference, S.A.M.*, April, 1947.



bered, however, that one grasp may be used to *get* a given part and another used to *place* it efficiently.

Analysis of many individual operations indicates that grasp may be classed readily into four divisions or types. They indicate the size of the parts which *normally* employ each type of grasp.

**Four Types of Grasp.** The four types of grasp are:

a. Three fingers and thumb (3F)

This grasp is used on any object large enough to permit placing three fingers and thumb around it (in at least two dimensions) without crowding and not large enough to require extension of the fingers to control it. This grasp, on parts of this size, is the easiest to obtain and in most cases provides maximum control. (See Fig. 273.)

b. Extend hand (H)

This grasp is used on any object where size requires extension of the hand, and weight, finish, or control requirements do not necessitate use of two hands. Control is good and readily obtained.

c. Two fingers and thumb (2F)

This grasp is used where it is impossible to obtain a three-finger grasp on an object because of its small size.

d. Two hands (2H)

This grasp is used where size, weight, design, or finish requires the use of two hands in moving the object, or where positioning is so difficult as to require a guiding hand.

**Limitations of Get.** In establishing standards for get times it seemed reasonable to include in get only two movements—transport empty and grasp (or select and grasp). Time for grasp is affected not only by the size of part grasped, as has already been discussed, but it is affected also by the variations imposed by the physical setup of the work place or the peculiar design of parts. These variations are more or less arbitrarily classified and are explained more completely below. Transport empty time is, in most cases, directly variable with distance. It has been treated as such with the exception of the larger distances which bring into play back and hip movements.

**Conditions of Get.** Each of the four types of grasp explained above varies with the operation conditions present. These variations are grouped into three classes, depending upon the facility with which grasp may be performed under those conditions. (See Fig. 273.)



Condition A—Very best grasp facility possible. The object is pre-positioned for grasp or the grasp is not hindered by other objects in contact with the object grasped.

Condition B—Good grasp facility is provided, but parts may be in quantities requiring some selection of a *single* part. No un-tangling or difficult separation is required.

Condition C—The design of parts or kind of finish prevents ready grasping. Parts may tangle, nest together, or be packed with separators or require special handling.

Figure 273 gives illustrations for each of the four different types of grasp (size of object) for each of the three different conditions of grasp. The standard time values in minutes are also shown. These values are correct when the transport empty distance is not over 8 inches.

**Limitations of Place.** The establishing of place times presented a more difficult problem since place is taken to include transport loaded, position (pre-position), and release load. Based on the amount of positioning or pre-positioning required, four classes have been determined from the study. These and several additional variations are explained below.

**Conditions of Place.** The variations in placing conditions have been grouped into four classes, depending largely upon the amount of positioning required. (See Fig. 274.)

Condition A—Positioning is normally little more than releasing the object or moving it slightly on the work place.

Condition B—Positioning of parts on or into definite locations with ample tolerances, simple open nests or fixtures, or assemblies with one point of location.

Condition C—Positioning of parts on or into difficult or complicated locations, assemblies, or fixtures requiring the positioning of parts with respect to two definite points, or location in two directions.

Condition D—Positioning is much the same as Condition C but in addition may involve close tolerances, greater care of finishes, three or more points or directions of location, or final application of force to assemble.

**"Dispose" Is a "Place."** As "Condition D dispose operations" are in reality a placing aside of a part, tool, or fixture, they have been evaluated on exactly the same base as place operations. An analysis



TABLE L  
STANDARD TIMES FOR BASIC DISTANCES

## GET TIMES IN MINUTES

Subdivision Number	Time	
1.	0.006	Obtain control of any object where a simple, single-part grasp is possible. (Part of any size, Condition A, and 3F parts, Condition B.)
2.	0.011	Obtain control of any object where simple grasp is not possible but parts have no tendency to tangle or nest. (Condition B with parts of any size other than 3F, 3F objects with Condition C.)
3.	0.017	Get large objects <i>H</i> requiring extended hand grasp with Condition C.
4.	0.019	Get small 2F objects in Condition C.
5.	0.024	Get large or weighty 2H objects with Condition C.

## PLACE TIMES IN MINUTES

Subdivision Number	Time	
1.	0.006	Place objects in Condition A position, any size other than 2H. Place 3F objects in Condition B position.
2.	0.011	Place 2H objects in Condition A position and 2F or <i>H</i> objects in Condition B position. Place 3F objects in Condition C position.
3.	0.019	Place 2H objects in Condition B position, or 2F or <i>H</i> parts in Condition C position, or 3F objects in Condition D position.
4.	0.024	Place small parts into very difficult locations, 2F parts in Condition D position.
5.	0.030	Place large parts into or on difficult assemblies, 2H objects in Condition C position.
6.	0.042	Place large parts into or on very difficult assemblies, 2H objects in Condition D position.

of a large number of dispose times indicates that, if properly classified under grasp and operation conditions, the time values established for place will apply.

**Method of Developing Time Values.** The motion-picture films of various assembly operations were analyzed, breaking down the operation cycles into gets, places, uses, and disposes, and the film time for each element was recorded. Subsequent analysis of the data was made, correcting for observed operator effort. The result of this analysis was the establishment of relatively consistent time values for the various combinations of size and for get or place conditions. The



time values do not represent the minimum values encountered for any particular combination, but are those selected as most representative of normal conditions and are corrected to represent normal operator effort.

### CORRECTIONS FOR TRANSPORT DISTANCES

As shown on page 439, there are only seven basic time values for get and place operations, although these values may be adjusted when necessary for particular operation variations. It was also pointed out that corrections for normal transport empty and transport loaded dis-

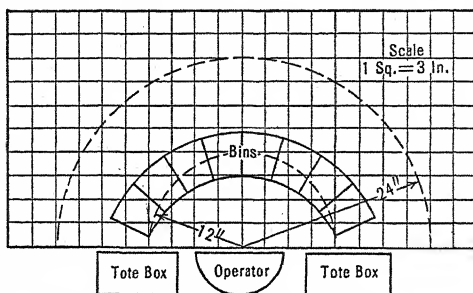


FIG. 275. Layout of typical work place.

tances could be made for each time value and thus eliminate repetition of this calculation for the user.

Where factory operations do not dictate otherwise, the assembly work place should be set up closely resembling the sketch shown in Fig. 275. Parts are to be supplied to the operator in *well-designed* bins, trays, hoppers, or other containers located in the areas indicated. In progressive assembly operations subassemblies will be delivered to the operator within the work area outlined (24 inches from the edge of fixture or bench nearest the operator). This setup provides the operator with an approved motion study work place and is the basis on which corrected standard time values have been established.

With the work place arranged as shown above, all but a very few of the operator's transport empty or transport loaded motions will be confined to distances less than 24 inches. As the majority of assembly parts are in the small or medium class, average transport empty or transport loaded distances will be much less than 24 inches. Consequently transport empty and transport loaded corrections are calculated slightly in excess of the anticipated average, and distances to 24 inches are allowed.



## GET TIMES CORRECTED FOR TRANSPORT EMPTY

## CLASS 1

	<i>Std. Time for Basic Distance</i> <sup>3</sup>	<i>Correction</i>	<i>Maximum Transport Empty</i>	<i>Standard to Be Used</i>
<i>Subdivision 1</i>	<i>0.006 minute</i>	<i>0.001 minute</i>	<i>12 inches</i>	<i>0.007 minute</i>

- A. Very best grasp facility possible, due to design or pre-positioning of object for grasp; no interference or hindrance with grasp by other objects. Size of object need not be considered. ( $3F$ ,  $H$ ,  $2F$ , and  $2H$ .)
- B. Get medium-sized parts ( $3F$ ) even when in quantities, provided no separation or untangling is required.

For Class 1 gets, transport empty distance is usually short, although 12 inches is allowed. This simple get is employed very infrequently for obtaining parts *to be brought* to the assembly; consequently, 12 inches maximum is ample. Ten and one-half inches is used as the distance in calculating the correction.  $(10\frac{1}{2} - 8) \times 0.0004 = 2\frac{1}{2} \times 0.0004 = 0.001$  minute.

*Examples.* (a) Get completed assembly for disposal.  
(b) Get bolts from bin.

## CLASS 2

<i>Subdivision 2</i>	<i>0.011 minute</i>	<i>0.002 minute</i>	<i>24 inches</i>	<i>0.013 minute</i>
----------------------	---------------------	---------------------	------------------	---------------------

- A. Grasp is easily made, but parts may be in quantities requiring some selection of a single part. Parts may be small ( $2F$ ), large ( $H$ ), or very large ( $2H$ ).
- B. The design or finish of parts prevents ready grasping, parts may tangle, nest together, or be packed in separators. Parts must be of medium size ( $3F$ ).

In this class of get, parts will normally be located at distances of 6 inches to 16 inches from the assembly. A transport empty distance of 12 inches should be ample, but allowance is made for 13 inches, giving a correction of 0.002 minute and allowing transport empty up to 24 inches.

*Examples.* (a) Get standard screws, washers, nuts, or pins from properly designed trays.  
(b) Get terminal box with terminal leads assembled.

## CLASS 3

<i>Subdivision 3</i>	<i>0.017 minute</i>	<i>0.004 minute</i>	<i>24 inches</i>	<i>0.021 minute</i>
----------------------	---------------------	---------------------	------------------	---------------------

Get large parts ( $H$ ) or object requiring extended hand grasp. Parts may tangle, nest together, etc.

A part of this class almost invariably will be supplied at a greater than average distance from the assembly; hence, a correction of 0.004 minute, permitting com-

<sup>3</sup> From Table L on page 439.



binning with (2F, Subdivision 4) parts, which are almost invariably supplied within 12 inches.

*Example.* Get toaster basket from tote box.

**Subdivision 4**      *0.019 minute*      *0.002 minute*      *24 inches*      *0.021 minute*

Get small parts (2F) whose design or finish prevents ready grasp or which tend to tangle or nest.

As explained above, small parts are almost invariably supplied within 6 inches to 16 inches from the assembly; hence, a correction for transport empty of 0.002 minute, allowing for 24 inches maximum transport empty.

*Example.* (a) Get coiled spring from tray, 12 inches transport empty.

#### CLASS 4

**Subdivision 5**      *0.024 minute*      *0.002 minute*      *24 inches*      *0.026 minute*

Get very large parts requiring two hand control (2H), the design or finish of which prevents ready grasping. Parts may tangle, nest together, etc. Very large parts, owing to space requirements, are normally supplied at distances greater than 24 inches. Also, there is usually but one very large part per assembly. For these reasons a correction was applied to bring the corrected standard time value into agreement with that of place, Class 4. This procedure is justified since an extra correction for transport empty over 24 inches is usually applied, and the error of this one element is proportionately small in a complete assembly cycle.

*Example.* (a) Get electric fan motor.

#### PLACE TIMES CORRECTED FOR TRANSPORT LOADED

##### CLASS 1

	<i>Std. Time for Basic Distance<sup>4</sup></i>	<i>Correction</i>	<i>Maximum Transport Loaded</i>	<i>Standard to Be Used</i>
<b>Subdivision 1</b>	<i>0.006 minute</i>	<i>0.001 minute</i>	<i>12 inches</i>	<i>0.007 minute</i>

- A. Place small (2F), medium (3F), or large (H) objects where positioning is normally little more than releasing the object or moving it slightly on the work place.
- B. Place medium-sized (3F) objects where positioning consists of some definite location, simple open nests, or fixtures. Loose tolerances.

As in Class 1 gets, a transport distance of only 12 inches is allowed. This is justified, as by far the greater majority of such places fall well within this distance.

*Examples.* (a) Reverse or turn over subassembly on work place.  
(b) Place waffle iron handle in nest in assembly fixture.

<sup>4</sup> From Table L on page 439.



## CLASS 2

*Subdivision 2      0.011 minute      0.002 minute      24 inches      0.013 minute*

- A. Place very large parts (2H) where positioning is normally little more than releasing the object or moving it slightly on the work place.
- B. Place small (2F) or large (H) parts which require some definite positioning in simple open nests or fixtures or on assemblies with one point of location. Loose tolerances.
- C. Place medium-sized parts (3F) in difficult or complicated locations or fixtures, requiring positioning of parts with respect to two points or locations in two directions.

Parts being placed in this class will be obtained from all locations of the work place. Transport loaded correction is based on the majority of parts being located within 12 inches and sufficient allowance made to include parts supplied at a maximum distance of 24 inches.

- Examples.* (a) (1) Turn over waffle iron assembly.  
(2) Place sandwich grill subassembly on work place.  
(b) Place washer on screw.  
(c) Place socket wrench on nut.

## CLASS 3

*Subdivision 3      0.019 minute      0.002 minute      24 inches      0.021 minute*

- A. Place very large parts (2H) where positioning consists of some definite location, simple open nests, or fixtures or assemblies with one point of location.
- B. Place small (2F) or large (H) parts where positioning is in difficult or complicated positions, assemblies or fixtures require the positioning of parts with respect to two points of location.
- C. Place medium-sized parts (3F) in B type locations but with close tolerances, or on assemblies with three or more points of location.

The basis for transport loaded correction is the same as for Class 2.

- Examples.* (a) Place 12-inch or 16-inch fan motor in fixture.  
(b) (1) Place screw in tapped hole, start thread only.  
(2) Place power driver on stud and nut.  
(c) Place small fan rotor shaft in end bearing.

## CLASS 4

*Subdivision 4      0.024 minute      0.002 minute      24 inches      0.026 minute*

Place small parts (2F) into very difficult assemblies requiring three or more points of location, close tolerances, or special precaution for finish. Place very small parts in inaccessible location. The basis for transport loaded correction is the same as for Class 2.



- Examples.* (a) Place cup washer over screw and lead.  
 (b) Place screw through hole in waffle iron cover into tapped hole.  
 Location is restricted by handle bracket.

**CLASS 5**

*Subdivision 5      0.030 minute      0.006 minute      24 inches      0.036 minute*

Place very large parts (2H) into difficult or complicated locations, assemblies, or fixtures, requiring the positioning of parts with respect to two definite points, or location in two directions.

Since very large parts are usually supplied at distances about 24 inches from the work place, a transport loaded correction of 0.006 minute is applied. The operator is given full allowance for a transport loaded distance of 24 inches, and where transport loaded is greater than 24 inches an extra correction is applied.

*Example.* Place waffle-iron unit on grid.

**CLASS 6**

*Subdivision 6      0.042 minute      0.006 minute      24 inches      0.048 minute*

Place very large parts (2H) into very difficult or complicated locations or fixtures, requiring location of three or more points or in three or more directions. Transport loaded correction is calculated as in Class 5.

*Example.* (a) Place toaster body in power screwdriver fixture, lining up two holes.

**Get and Place Times Corrected for Transport Distances over 24 Inches.** Occasionally get or place operations require transport distances greater than 24 inches, for which condition a correction must be applied. Transport distances in excess of 24 inches are fairly well limited to a maximum of 36 inches or a maximum correction of 0.0072 minute (12 inches  $\times$  0.006 minute per inch). (See Note 3 below Fig. 273.)

The average transport distance in this range will be somewhat less than 36 inches; so a liberal correction of 0.006 minute is allowed. This value is added to each transport empty and transport loaded which exceeds 24 inches.

On some infrequent assemblies it is necessary to effect a transport empty or transport loaded greater than 36 inches. When this is necessary the operator must "walk and carry." For distances up to 7 feet operators usually shuffle sideways. Analysis has shown that a value of 0.007 minute per foot (each foot over 36 inches up to a total of 7 feet) is a reasonably accurate value to apply.



This same correction will apply in those instances where an operator moves from one fixture to another in a progressive assembly cycle.

### Development of Standard Times for Simultaneous Gets and Places.

In the preceding pages four get times and six place times were developed for direct use with transport distances up to 24 inches except for simple gets and places which were allowed only 12 inches. These times were developed for the getting or placing of a single part *only*. Whenever possible, motion economy requires the getting and placing of two parts, one in each hand simultaneously.

#### Class 1

Basic time for Class 1 Get (Table L)	= 0.006 minute
Transport empty correction for 12 inches maximum instead of 8 inches. <sup>5</sup> $(12 - 8) \times 0.0004 = 4 \times 0.0004$	= 0.0016 minute
Corrected time value for 12 inches = $(0.006 + 0.0016)$	= 0.0076 minute
Simultaneous get factor (see Note on Fig. 273)	= 1.3
Standard time for simultaneous get $0.0076 \times 1.3 = 0.0099$ use	= 0.010 minute
Basic time for Class 1 Place (Table L)	= 0.006 minute
Transport empty correction for 12 inches maximum instead of 8 inches. $(12 - 8) \times 0.0004 = 4 \times 0.0004$	= 0.0016 minute
Corrected time value for 12 inches = $(0.006 + 0.0016)$	= 0.0076 minute
Simultaneous place factor (see Note on Fig. 274)	= 1.4
Standard time for simultaneous place $0.0076 \times 1.4 = 0.01065$ use	= 0.011 minute

#### Class 2

Basic time for Class 2 Get (Table L)	= 0.011 minute
Transport empty correction for 13 inches instead of 8 inches (24 inches maximum) $(13 - 8) \times 0.0004 = 5 \times 0.0004$	= 0.002 minute
Corrected time value for 13 inches = $(0.011 + 0.002)$	= 0.013 minute
Simultaneous get factor (see Note on Fig. 273)	= 1.3
Standard time for simultaneous get $0.013 \times 1.3 = 0.0169$ use	= 0.017 minute
Basic time for Class 2 Place (Table L)	= 0.011 minute
Transport empty correction for 13 inches instead of 8 inches (24 inches maximum) $(13 - 8) \times 0.0004 = 5 \times 0.0004$	= 0.002 minute
Corrected time value for 13 inches = $(0.011 + 0.002)$	= 0.013 minute
Simultaneous place factor <sup>6</sup> (see Note on Fig. 274)	= 1.5
Standard time for simultaneous place $0.013 \times 1.5 = 0.0195$ use	= 0.020 minute

<sup>5</sup> As "Simultaneous Gets" include the large class of simple gets, the average transport empty distance is properly at the maximum of the class, 12 inches.

<sup>6</sup> It was decided to allow the larger simultaneous factor for all classes except Class 1 in order to provide for simultaneous placing of both like and unlike parts.



Standard times including transport empty and transport loaded have been developed for "get or place two parts simultaneously" for the same conditions outlined above for single parts. The method used in this development is shown for Time Classes 1 and 2, gets and places.

**Summary.** The foregoing has presented a means of classifying the great majority of the assembly operations found in the Appliance Section. It establishes a means of defining operations in a manner which largely eliminates variations in judgment on the part of those using the data.

When familiarity with the basic operation conditions has been attained, the proper classification of any operation is easily and quickly recognized. It will be noted that the two figures (Figs. 273 and 274) contain only *seven* different time values for the total twenty-seven separate combinations of conditions. For practical purposes these time values may be increased directly by the average amount of transport empty or transport loaded correction required by the standard work place. Such time values are shown in Figs. 276 and 277.

It should be noted that the time values given in this chapter apply to carefully defined groups of motions. Moreover, the classifications shown are mainly used for assembly operations of electrical appliances.

Although the material presented in this chapter is largely limited in its application to assembly operations in the plant of the company that developed it, the method has wide application as demonstrated by the fact that an increasing number of companies are using it.



## CHAPTER 27

### DETERMINING TIME STANDARDS FOR ASSEMBLY OPERATIONS AN APPLICATION

**Convenient Use of Standard Times.** A "Standard Times Computation Sheet" has been constructed, based upon the standard times established in the preceding chapter. This computation sheet, reproduced in Figs. 278 and 279, combines established time values into an easily used table. An experienced analyst will find this table to be more easily and quickly used on assembly operations than a stop watch. As it is based on an analytical method with proved therblig time values, it produces results which are largely free from variations due to the human element. It assists the user in analyzing the operations, permitting undivided attention to be applied to analysis as the operation progresses.

The back or "Breakdown" side of the computation sheet (Figs. 279 and 282) consists of six major sections as numbered in the small circles. These six sections are:

- (1) *Operation.* Description of the operation analyzed, including designation of the product involved.
- (2) *Elements of the Operation.* The chronological description of the assembly cycle. In this section the user records the successive elements of assembly for each part or tool which the operator gets, places, or uses.
- (3) *Standard Times.* Sections 3, 4, and 5 comprise a tabulation of the standard
- (4) therblig time values established for: (3) get or place parts within normal
- (5) distances; (4) correction for operations exceeding normal distances; (5) use times of common assembly tools and machines. The time values are given in column 5(b) and are recorded in column 5(a).
- (6) *Total Time in Minutes.* This space is provided for recording total assembly time or, where desirable, the time for each group of elements.

It will be noted that Section 3 consists of six columns headed C1 through C6. These columns represent the six classes of get *G* or place *P* times developed for individual parts.

Column C1 includes three subcolumns: on the left is a column headed *G* and *P*, 0.007. This column is used for any get or place ele-



## STANDARD TIMES COMPUTATION SHEET

DEPT.:		DEPT. NO.:		ANALYST:	
DRAWING NUMBER:		DATE:		FOREMAN:	
Time to Move = .40 x No. Bxs. = .40 x = Min.		Fatigue Allowance = %		Replenish Sm. Parts = %	
Total Time In Minutes + Move Tote Bx. Time/Pc.		+ Allowance % or		STANDARD TIME IN MINUTES	

WORK PLACE Scale: 1 unit = 3"		EQUIPMENT (Check on Work place):	

COMMENTS:

GENERAL ASSEMBLY STANDARD TIMES		SIZE OF OBJECT:		M (3F)	L (H)	S (2F)	V.L. (2H)	TIME CLASS
OPERATION CONDITIONS				TIME IN MINUTES				
Get Condition A	Very best grasp facility possible. The object is pre-positioned for grasp, or the grasp is not hindered by other objects in contact with the object grasped. Size of object need not be considered.	.007	.007	.007	.007			C 1
Get Condition B	Grasp is easily made but parts may be in quantities requiring some selection of a single part. No untangling or difficult separation is required.	.007	.013	.013	.013			C 2
Get Condition C	The design of parts or kind of finish prevents ready grasping. Parts may tangle, nest together, or be packed with separators, or require special handling.	.013	.021	.021				C 3
Place Condition A	Place objects where positioning is normally little more than releasing the object or moving it slightly on the work place.	.007	.007	.007			.013	C 1 C 2
Place Condition B	Place objects where positioning consists of some definite location, simple open nests, or fixtures with ample tolerances, or assemblies with one point of location.	.007	.013	.013			.021	C 3
Place Condition C	Place objects where positioning is in difficult or complicated locations. Assemblies or fixtures requiring the positioning of parts with respect to two definite points, or location in two directions.	.013	.021	.021			.036	C 4 C 5
Place Condition D	Positioning is much the same as Condition C but in addition may involve close tolerances, greater care of finishes, three or more points or directions of location, or application of force to assemble.	.021	.026	.026			.048	C 6

FIG. 278. Standard Times Computation Sheet—Front or “Summary Side.” Size  $8\frac{1}{2} \times 11$  inches.



[illegible]

Fig. 279. Standard Times Computation Sheet—Back or “Breakdown Side.”



ment involving one individual part and included in the definitions of Class 1 get or place (see Figs. 276 and 277). The center column headed *G2*, 0.010, is used for any get element involving parts and conditions defined in Class 1, where two parts are obtained simultaneously. Similarly, the right-hand column headed *P2*, 0.011, is used for simultaneous placing of two parts, one in each hand, where Class 1 conditions apply.

**Standard Times, Definition of Class Times.** Familiarity with the six classes used in the computation sheet may be obtained more readily by a study of the charts shown in Figs. 276 and 277. They represent the time values of the two charts, Figs. 273 and 274, corrected for normal operation transport distances.

It will be noted that the first four classes of place have the same time value as the four classes of get. It must be remembered, however, that combined get and place classes do not represent the same combinations of grasp and operation conditions.

**Use of the Computation Sheet.** The Standard Times Computation Sheet may be used for estimating assembly costs on pre-production designs or for establishing time standards on assembly operations where procedure and methods are already in effect.

*Example. Assemble parts of waffle iron.* The following example taken from the assembly line of the No. 119Y 197 waffle iron is used to explain the procedure:

1. *Operation*

The operation consists of: Assemble unit and cover to lower waffle iron grid casting.

2. *Equipment*

The equipment provided for this operation is:

- (1) One Millers Falls power nut-driver
- (2) Conveyorized bench
- (3) Chair
- (4) Two tote boxes and floor stands
- (5) Two cardboard boxes (4"  $\times$  5"  $\times$  3" deep)

3. *Parts*

There are five parts (see Fig. 280) used in this assembly cycle:

- (1) Lower grid-casting in tote box to operator's left.
- (2) Unit, porcelain ring and element subassembly, on conveyor belt in center of bench.
- (3) Cover, in tote box to operator's right.
- (4) Stud,  $\frac{1}{4}$ "-20, 1" long in cardboard box.
- (5) Nut,  $\frac{1}{4}$ "-20, in cardboard box.

4. *Fixture*

No fixture is used.



5. *Description of Cycle*

- (1) The operator reaches into the tote box on the left and selects one grid casting.
- (2) She lifts the casting, examining the edges, and face, and lays it on the bench, face down with the hinge lug toward her.
- (3) She reaches with left hand to a pile of units on the conveyor, picks up the top unit, and with both hands—
- (4) Places it on the grid casting with the wire leads above the hinge lug.

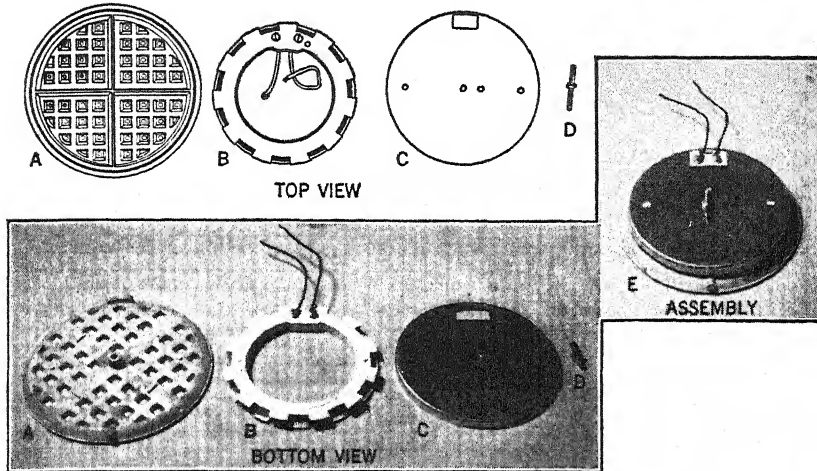


FIG. 230. Parts for waffle-iron lower grid assembly. A. Lower grid casting; B. Unit-porcelain ring and element subassembly; C. Steel cover; D. Stud and nut; E. Assembly of parts A, B, C, and D.

- (5) While the left hand straightens and raises these leads the right hand holds the unit.
- (6) The right hand then reaches into the tote box at right and obtains one cover plate which is then—
- (7) Placed over the leads onto the grid and unit.
- (8) The right hand then reaches into the box containing the studs, obtains one, and—
- (9) Inserts it through the cover into a tapped hole in the casting.
- (10) Then the right hand reaches to the second box and obtains the nut and—
- (11) Starts it on the stud. During these last operations (8 through 11) the left hand has held the assembly. After starting the nut the right hand—
- (12) Obtains the power driver (meanwhile the left hand has pushed the assembly to a rough position below the power driver), then—
- (13) The right hand places the power driver on the stud and nut and—
- (14) Operates the power driver. As the right hand—
- (15) Releases the power driver the left hand lifts the assembly from the bench. The right hand then—
- (16) Grasps the assembly and—







[illegible]

Fig. 282. Standard Times Computation Sheet for waffle-iron assembly—Back.

G or P == "Get" or "Place" parts individually  
G2 or P2 == "Get" or "Place" two parts (one  
Walking == Transport Empty & Transport Loaded



- (17) Places it on a stack of completed assemblies to the right of the work place and returns to the work place empty.

## Procedure

### 1. Record all Pertinent Data for the Job

- a. On the front or "Summary Side" of the Computation Sheet (Fig. 281) write, in the spaces indicated: the department, department number, analyst's name, drawing number of the assembly, date, and the name of the foreman in charge.
- b. Also, list under "Equipment," and note position of each item on the sketch, those pieces of equipment and all parts provided for the operation.
- c. On the back of the sheet write a brief title or description of the operation in the section headed operation (section 1 of Fig. 282).

### 2. Analyze the Assembly Cycle

- a. Reduce the operation to a succession of smaller elements based on a combination of "Get and Place" or "Get, Place, Use, and Dispose" for each part and tool in the cycle.
- b. List these elements on the back of the sheet in section 2 (Fig. 282) under "Elements of the Operation."
- c. Analyze each of these elements successively. Evaluate any inherent qualities or peculiarities of design or setup for each element and determine the proper classification of each in relation to the class definitions.
- d. Check the proper class (sections 3 and 5) opposite each assembly element.
- e. Check in section 4 those elements involving transport distances greater than the allowed maximum for the class.
- f. Analyze complete assembly and note possible need for any inspection before, during, or after assembly. Indicate probable frequency of such inspection if required.
- g. Analyze the setup for allowances for replenishing both major and small parts. Make the proper notations required.

### 3. Calculate the Assembly Operation Time

- a. Add the check marks in each column of sections 3, 4, and 5 (Fig. 282).
- b. Multiply the standard time for each by the number of check marks in that column.
- c. Total the results and enter in column 6.

### 4. Standard Time Calculation

- a. The total time for the assembly cycle, foot of column 6 (Fig. 282), is entered on the summary page (Fig. 281), following "Total Time," in this case 0.434 minute.
- b. The allowance for replenishing parts is calculated in two parts.
  - (1) Two tote boxes, 20 parts in each, supply the two large parts. Proper values are inserted in the formula,  $\frac{(0.40 \text{ min.} \times \text{no. boxes})}{(\text{No. pcs. per box})} = \text{time per}$



cycle, on the summary page (Fig. 281). The time per cycle is calculated and posted.  $\left( \frac{0.40 \times 2}{20} = 0.040 \text{ min.} \right)$

- (2) Replenishing small parts, nut and stud, is handled on a percentage basis. Two per cent is added to the operator's fatigue and personal allowance for this item.
- c. To the Total Time (a) above is added the time per cycle for moving tote boxes. The sum of these two values is entered in the center of the fourth line.  $(0.434 + 0.040 = 0.474 \text{ min.})$
- d. The total percentage allowance given the operator for fatigue and personal time and for other reasons is then recorded to the right on the third line. This percentage in this instance is 8 per cent fatigue and personal + 2 per cent for parts replenishing, or a total of 10 per cent.
- e. This percentage (d) is added to the total time (c), and the sum in minutes is entered on the fourth line at the right, preceding "Standard Time."  $0.474 + (0.10 \times 0.474) = 0.474 + 0.047 = 0.521 \text{ min.}$

### DETAILS OF ANALYSIS

**Analysis of the Cycle.** In the "Description of Cycle" the operation has been outlined in step form. Breaking this outline down into Elements of the Operation in form appropriate for recording on the back of the Computation Sheet (Fig. 282), we have:

1. Get (1) and Place (2) grid on table (see page 451).
2. Get (3) and Place (4) unit on grid.
3. Get and Place (5) wire leads. Adjustment only. (This is a simple position-adjusting operation.)
4. Get (6) and Place (7) cover.
5. Get (8), Place and Start (9) stud.
6. Get (10), Place and Start (11) nut.
7. Get (12), Place (13), Use (14), and Dispose (15) of power driver.
8. Get (16) and Dispose (17) of assembly.
9. Inspect Grid Castings [included in (2)]. An inspection element is kept separate from the cycle elements as unusual conditions may alter its importance from time to time. In this particular instance the inspection is 100 per cent.

**Analysis of Elements of the Operation.** Section 1 (Operation) and Section 2 (Elements of Operation) of the "Breakdown" side of the Computation Sheet (Fig. 282) have now been filled in. The method of evaluating each Element is presented below. In this example, the letters *G*, *P*, *D*, and *S* are used for the sake of clarity instead of check marks. They indicate the nature of the check, Get, Place, Dispose, and Start, respectively.



### 1. *Get and Place Grid Casting on Work Place*

*Get* The grid casting is supplied in a tote box to the operator's left. The distance from the work place is 30 inches. The grid is a *large* part leaning against others. This is a Class 3 Get as the parts are not supplied with easy grasp provided.

Check *G* and *P*, Class 3, 0.021 minute.

*Place* The grid is placed on the work place bottom side up with the hinge lug toward the operator. This is a Class 3 Place as the grids are not supplied in a manner to permit this position automatically, hence, although the part does not go into a fixture, Class 3 is preferred to Class 2.

Check *G* and *P*, Class 3, 0.021 minute.

Since the grid casting is supplied at 30 inches an additional transport empty and transport loaded allowance is required.

Check transport empty and transport loaded over 24 inches up to 36 inches, 0.012 minute.

### 2. *Get and Place Unit on Grid*

*Get* The porcelain units are supplied by the previous operator who stacks them, five or six per pile, about 20 inches from the work place. There is no difficulty encountered in grasping the unit. This is a Class 2 Get as the parts are in quantities, but there is no tangling or difficult separation involved.

Check *G* and *P*, Class 2, 0.013 minute.

*Place* The brick is placed on the grid casting lining up two recesses in the brick with two bosses on the grid. The bricks are always supplied right side up. This is a Class 5 Place as the part is guided by two hands into a position involving two points of location.

Check *P*, Class 5, 0.036 minute.

### 3. *Get and Place Wire Leads*

This is merely an adjustment of the leads, already assembled to the brick, to facilitate the next assembly operation.

*Get* The left hand grasps the two leads, which are pointing toward the operator and afford easy grasp. A simple Class 1 Get.

Check *G* and *P*, Class 1, 0.007 minute.

*Place* The left hand raises the leads to a vertical position and straightens them as they slide through the fingers. A simple Class 1 Place.

Check *G* and *P* Class 1, 0.007 minute

### 4. *Get and Place Cover*

*Get* The covers are supplied in a tote box to the operator's right at a distance from the work place of about 30 inches. The cover is a large part leaning against, or piled upon, others. This is a Class 3 Get as the parts are not supplied with easy grasp provided in Class 2.

Check *G* and *P*, Class 3, 0.021 minute.

*Place* The cover is placed over the vertical leads from the unit (one point of location) and with two hands is placed on the assembly, lining up two holes in the cover with two bosses on the brick (second and third point



of location). Large parts placed with two hands, location on 3 points of assembly require Place Class 6.

Check *P*, Class 6, 0.048 minute.

Since the cover is supplied at 30 inches an additional transport empty and transport loaded is required.

Check transport empty and transport loaded over 24 inches up to 36 inches, 0.012 minute.

5. *Get, Place, and Start Stud*

*Get* Screws, nuts, and other nontangling hardware items normally are provided with Class 2 *Get*. In this case well-designed trays have not been provided for the stud. Grasp is hindered by the size and shape of the containers, and Class 3 *Get* is used.

Check *G* and *P*, Class 3, 0.021 minute.

*Place* The stud is inserted through a large hole in the cover into a tapped hole in the grid. The stud and tapped hole are designed to facilitate assembly and would normally be Class 2, but the difficulty of placing through the hole in the cover justifies use of Class 3.

Check *G* and *P*, Class 3, 0.021 minute.

*Start* Place includes insertion of the stud but rigidity requires an additional turning of the stud. Allow a simple *Get* and *Place* Class 1 for turning the stud an additional one or two threads.

Check *twice G* and *P*, Class 1, 0.007 minute.

6. *Get, Place, and Start Nut*

*Get* The nut is also supplied in an improper container. This is also a Class 3 *Get* for the same reasons as 5 above.

Check *G* and *P*, Class 3, 0.021 minute.

*Place* The nut requires as much location as the stud, but in addition must be kept perpendicular to the stud in starting. This element is usually Class 3.

Check *G* and *P*, Class 3, 0.021 minute.

*Start* Check *twice G* and *P*, Class 1, for same reason as 5 above.

7. *Get, Place, Use, and Dispose of Power Driver*

*Get* The power driver is suspended over the work place, providing nearly perfect grasp facility. This is properly a Class 1 *Get*. However, the left hand is positioning the assembly during the *Get* so the *Get* is properly a Class 1 simultaneous *Get*.

Check *G* 2, Class 1, 0.010 minute.

*Place* Placing the power driver on the stud and nut requires locating the driver in two directions. (Class 3 definition.)

Check *G* and *P*, Class 3, 0.021 minute.

*Use* Driving the stud and nut with the power driver has been determined on an average basis and a separate column incorporated for this element. Check Process times, Power Driver, 0.020 minute.

*Dispose* As the power driver is spring suspended, disposing of it is a simple motion to approximate position and a release. This is Class 1 *Place*.

Check *G* and *P*, Class 1, 0.007 minute.



8. *Get and Dispose of Assembly*

*Get* The left hand has been holding the assembly during the use of the power driver. While the right hand disposes of the driver the left raises the assembly, positioning it for grasp. This is necessary as the progressive assembly moves from left to right and the completed assembly is stacked at the right. Since the assembly is pre-positioned for grasp, the *Get* is Class 1.

Check *G* and *P*, Class 1, 0.007 minute.

*Dispose* The assembly is placed on a stack of previously completed assemblies.

This requires precise positioning, definite location. Use, *Place*, Class 3.

Check *G* and *P*, Class 3, 0.021 minute.

The dispose distance is over 24 inches so check transport empty and transport loaded over 24 inches up to 36 inches, 0.012 minute.

9. *Inspect Grid Castings, 100 Per Cent*

In each cycle it is necessary to give the grid casting a quick inspection. This element is an addition to the place element (1). It has been evaluated on therblig time values.

1. Examine casting for tapped hole:	
a. Focus eyes on hole	0.002 minute
b. Examine hole	0.003 minute
2. Examine edge for grinding marks and face for cleanliness:	
a. Turn casting over	0.003 minute
b. Focus eyes three times ( $3 \times 0.002$ )	0.006 minute
c. Examine three points ( $3 \times 0.003$ )	0.009 minute
d. Turn casting over	0.003 minute
Total	<hr/> 0.026 minute

**Classification of Parts Assembled in a Department.** After the basic classification has been worked out and put in use it is customary to compile a list of the parts assembled in a given department, listing them by (kind of grasp) size of part.

The following is an abbreviated list of the parts for the Appliance Manufacturing Department:

1. *Small*

Parts held by two fingers and thumb. Any parts whose small size will not accommodate three fingers and thumb, fingers not crowding.

Examples: Screws  
Nuts  
Washers  
Studs  
Pins

Bearings (mixer)  
Brushes (carbon)  
Fuse links  
Fuses (small cartridge or percolator)



2. *Medium*

Parts held by three fingers and thumb. Any parts which can accommodate three fingers and thumb without crowding or extending of the hand. These parts are the easiest to control.

Examples: Percolator units	Mixer and small fan motors
Standard sockets	Radio tubes
Waffle iron side handles	Standard outlets
	Standard glass fuses

3. *Large*

Parts held by the extended hand. Any parts which require the extending of the hand to hold them.

Examples: Toaster baskets	Large fuse cut-outs
Percolator lids	Sandwich grill support
Percolator body	Waffle grill support
Percolator bases	

4. *Very large*

Parts held by two hands. Any parts whose size, weight, design, or finish makes a two-handed control necessary.

Examples: 12" and 16" fan motor	Waffle iron
Waffle iron base	Mixer motor (less handle)
Bundle of unwrapped cords	Roaster body
	Fan guards (large)



## CHAPTER 28

### MOTION AND TIME STUDY TRAINING PROGRAMS

The work of the motion and time study department in some organizations is not as successful as it should be because members of the organization do not understand how such studies are made and consequently they do not give this department the support and cooperation it should have. Often this lack of understanding extends from the president of the company to the foremen and the workmen in the plant.

One of the best ways to overcome such difficulties is to acquaint all members of the organization with motion and time study methods and procedures through well-organized and carefully conducted training programs. Some typical programs of this kind are described here.

#### MOTION STUDY TRAINING PROGRAMS

Before any job can be started someone must plan it and set it up. This preliminary work includes determining the steps to be followed in doing the work, selecting the tools and equipment to be used, and training the operator.

When the production of a given article is large, staff engineers usually work out the details and aid the foreman and supervisors in putting the job into production. However, most work is not highly repetitive, and an operator may do several different jobs during the course of a day or a week. In such cases the supervisor usually decides how the job is to be done, lays out the work place, selects the tools and equipment, and instructs the operator. For this reason it is desirable that those people in immediate charge of operations know the fundamentals of good work methods. Even when the production of the article is expected to be large and when industrial engineers are assigned to work out the manufacturing methods, the foremen and supervisors usually play an important part in aiding the engineers to develop the procedures to be followed. Here, too, it is desirable for the supervisor to have a working knowledge of the industrial engineer's technique as it pertains to methods improvement.



However, in the final analysis it is the operator who does the job. It is the operator who uses the tools and equipment selected by the supervisor or the engineer and employs the methods suggested by him. Therefore it is logical that the operator too should understand those methods and techniques which will enable him to do his job in the easiest and most efficient manner possible.

It has been demonstrated many times that both supervisors and operators can profitably apply the principles of motion economy. Naturally the supervisor should take the initiative in using these tools for improving job methods. When this is done the operator may be expected to absorb this knowledge more quickly either through instruction from the foreman or through a formal training course.

Training programs designed to present the procedures and techniques of the industrial engineer to top executives, foremen, supervisors, and operators provide an effective means of promoting better work methods in any organization. A methods improvement training program to be most effective should be developed to meet the needs of the particular group to receive the training. The two program outlines comprising Appendix A and Appendix B of this book show in detail the type of course that is proving effective in industry today. It is not expected that these outlines will be used exactly as they are presented here; rather it is hoped that they may serve as a guide to those who are confronted with the problem of designing a program for their own particular group. The cases and illustrations referred to in the outline will be found in the author's books. The motion picture films suggested are available on a loan basis to anyone in the United States wanting to use them. It is obvious that a company beginning a methods improvement training program will want to obtain cases and illustrations from its own organization as soon as possible. Many companies, however, must start with little material of their own.

As has already been discussed, the three main tools for developing better methods are (1) process analysis, (2) equipment utilization, and (3) operation study (including micromotion study). In some cases one or two of these phases of the subject should receive greatest emphasis. For example, if a plant operates mainly heavy equipment, and if much of the work is group activity, process analysis and equipment utilization should be emphasized and the time devoted to operation study should be reduced.

**A Preview of the Program.** A methods development program like any other important activity in an organization must be understood



and fully supported by top management if it is to be successful. In fact, every executive, manager, and supervisor must be acquainted with the purposes and objectives of the program and must understand the principles and approaches used in developing better work methods. For this reason it is essential that a preview of or introduction to the

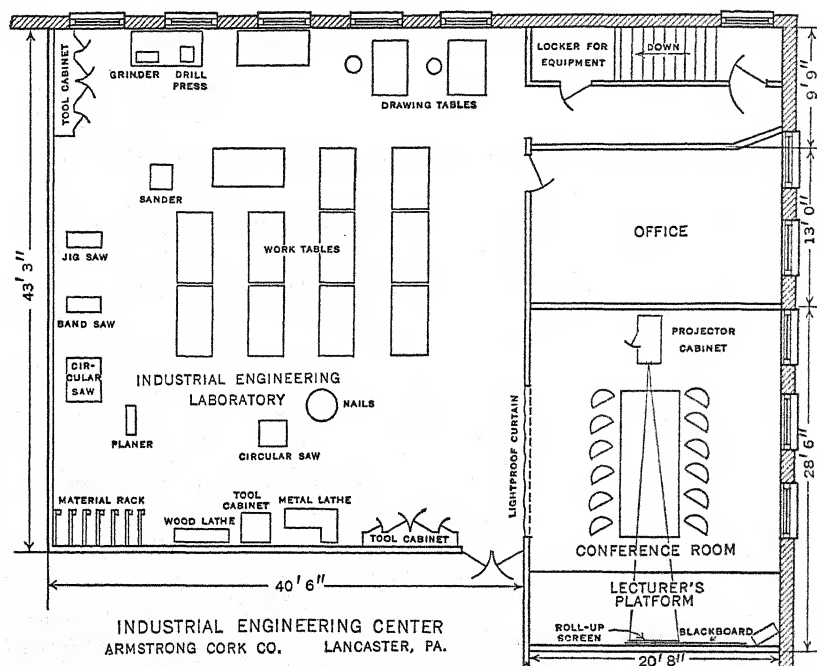


Fig. 283. Floor plan of Industrial Engineering Center at the Armstrong Cork Company.

program be given to top management. The "preview outline" described in Appendix A requires 2 to 3 hours to present, and this represents the minimum time that should be allowed for this phase of the program. A fuller presentation is preferable if time is available.

As has already been indicated, the program must be worked out to fit the particular needs of the organization, and the preview given at the very outset should reflect the type of program that will follow.

**The Program.** In many cases it has been found profitable to present the program to industrial engineers, supervisors, foremen, process engineers, tool and jig designers, mechanical engineers, group leaders, and key operators. Thirty to 40 hours are required to complete the pro-



gram outlined in Appendix B. Perhaps greatest success is obtained when the program is given in one continuous period of approximately 2 weeks. The forenoons may be devoted to conference room discussions and demonstrations and the afternoons to working on projects or problems. A combination shop and laboratory (see Figs. 283, 284, and 285) is needed if project work is included in the program. If it does not seem feasible to present the entire program in one continuous session,



FIG. 284. Conference room for Methods Development Program.

the material may be given in a series of 1-, 2-, or 3-hour sessions held once or twice a week as conditions seem to indicate.

**A Specific Case.** A successful Methods Development Program has been under way for several years at the Armstrong Cork Company. This organization employs approximately 12,000 people in seventeen different plants in this country. The company is well managed, and it has had a staff of well-trained industrial engineers in each of its plants for many years.

An Industrial Engineering Center was established at the main plant and a Methods Development Program was inaugurated in order to give greater emphasis to this phase of industrial engineering in the company, to standardize the techniques and procedures among all plants and personnel of the organization, and to lay the groundwork for a



methods development program for foremen and supervisors that later would be conducted in each plant.<sup>1</sup>

Industrial engineers, process engineers, mechanical engineers, and production supervisors from the various plants came to the Industrial Engineering Center in groups of 10 to 15 for 2 weeks' training, con-

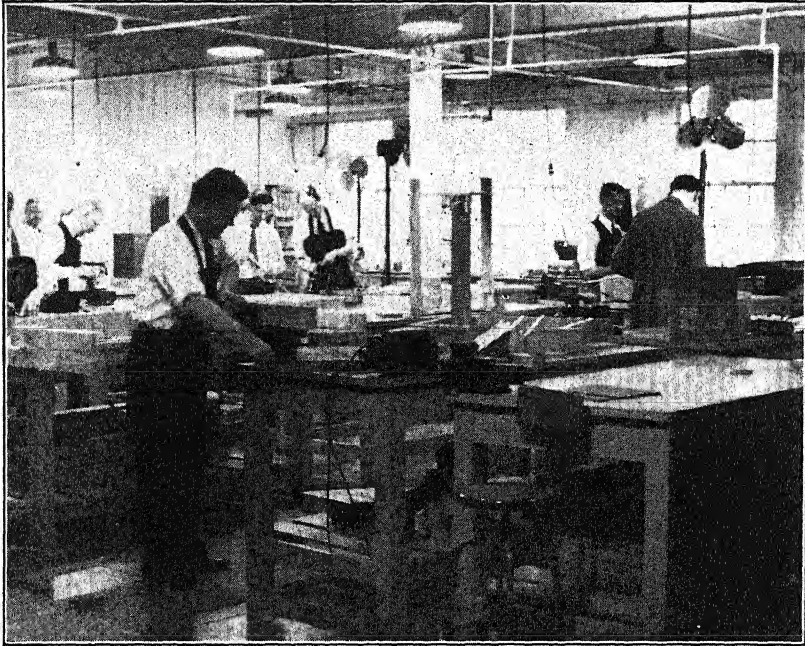


FIG. 285. Laboratory for project work in connection with the Methods Development Program.

sisting of conferences and project work. At the completion of this program a shorter series of conferences was held in each plant for foremen and supervisors. This program was designed especially to fit the needs of the particular plant in which it was to be presented. An important feature of these conferences was the project work which each foreman did in his own department. The methods and techniques presented in the conferences were applied to specific problems by the foreman. The industrial engineers in the plant as well as the conference leader

<sup>1</sup> H. B. Oberg, "The Fundamentals of a Good Methods Training Program," *Proceedings of the National Time and Motion Study Clinic*, pp. 7-9, 1945. Also John V. Valenteen, *Modern Management*, Vol. 8, No. 5, July, 1948.



were available to assist the foreman when he needed help with his projects.

The Methods Development Program was designed to be the first part of a long-range training program in the field of industrial engineering in this organization.

Figure 283 is the floor plan of the Industrial Engineering Center. Figure 284 shows one end of the conference room, and Fig. 285 shows a group of men working on projects in the laboratory which adjoins the conference room.

**Twenty Years of Motion Study Training.** The Fort Wayne works of the General Electric Company has maintained continuously for nearly twenty years a motion study training program. From the outset they saw the importance of training all members of their supervisory personnel in motion study methods and techniques.

In 1928 representatives from the various plants of the General Electric Company were sent to Schenectady, where training in motion study was given. This training included both classroom instruction and the application of the principles in the laboratory and factory. These representatives, after thorough training, returned to their respective plants and proceeded to carry out training programs of their own.

The motion study training program was started at the Fort Wayne works by L. P. Persing in January, 1929, when one class of planning and time study engineers was held. During a 3-year period the following classes were conducted: <sup>2</sup>

3 Classes of planning and time study engineers (beginners)	27
4 Classes of planning and time study engineers (advanced)	61
16 Classes of general foremen, foremen, assistant foremen, leading operators	268
2 Classes of special tool and machine designers	27
3 Classes of leading operators, expert workers, and personnel workers (women)	42
1 Class of plant-construction engineers	22
1 Class of expert workers (assemblers)	16
<hr/>	
30 Total number of classes	Total number of persons trained 463

During the period in which the training was being carried on, new methods were devised by the application of motion study principles. In all, 96 jobs were studied and the methods revised. The new methods brought about an average reduction in time of 40 per cent; and the

<sup>2</sup> L. P. Persing, "Motion Study—The Teacher," *Factory and Industrial Management*, Vol. 83, No. 9, pp. 337-340, September, 1932.



tools and equipment necessary to put the improved methods into effect cost 7.4 per cent of the total savings.

Motion study training has been given continuously since the program was started in 1929. During the last 3½-year period the following classes in motion and time study have been conducted at the Fort Wayne works:

6 Classes in motion study for time study men, planners, tool designers, and plant engineers (20 periods of 1½ hours each, biweekly)	53
5 Classes in time study for time study trainees, planners, and cost reduction men (20 periods of 1½ hours each, biweekly)	43
8 Classes in time study for general foremen, foremen, planners, and office leaders (7 periods of 1½ hours each, weekly)	87
17 Classes in combined motion and time study for foremen, leading operators, setup men, time study men, and planners (15 periods of 1½ hours each, weekly)	197
47 Classes in job method improvement for general foremen, foremen, planners, time study men, and tool designers (5 periods of 2 hours each, biweekly)	590
37 Classes in method analysis (method improvement refresher course) for general foremen, foremen, time study men, planners, tool designers, key cost men, production men, and draftsmen (5 periods of 2 hours each, weekly)	437
<hr/> 120 Total number of classes	<hr/> Total number of persons trained 1407

Thousands of profitable projects have been worked out by members of the supervisory force in connection with the motion study training programs during this period. Moreover, this type of training has promoted a better understanding between the foreman and the industrial engineer and has made the work of both groups more effective.

At the Metropolitan-Vickers Electrical Company in Manchester, England, training in the principles of motion study has been given to groups of time study men, foremen, draftsmen, tool designers, production men, and employee representatives. During a period of two years alone ". . . for those investigations actually completed by the Motion Study Section, the average increase in the daily production per operator in 70 investigations has been 173 per cent."<sup>3</sup> In addition to this, many valuable suggestions were made by the other groups who received this training.

To cite another case, a midwestern manufacturing company with approximately 7000 employees conducted the following training program in motion study principles during one year.

<sup>3</sup> A. G. Shaw, "Motion Study Applied to Engineering," *Journal of the Institution of Production Engineers*, Vol. 13, No. 7, p. 383, London.



13 Periods of $1\frac{1}{4}$ hours each (weekly)	
1 class of general foremen	28
15 classes of foremen, assistant foremen, and group leaders (men)	206
2 classes of group leaders (women)	30
20 Periods of $1\frac{1}{4}$ hours each (weekly)	
8 classes of time study men and planning engineers	100
8 Periods of $1\frac{1}{4}$ hours each (biweekly)	
1 class of executives—works manager, assistant managers, superintendent of costs, planning, engineering, etc.	24
	<hr/>
Total number receiving training	388

**Training New Employees and Apprentices.** The several training programs described above included a rather detailed presentation of the technique of micromotion study as well as a study of the principles of motion economy. A less comprehensive program was developed at Metropolitan-Vickers for training all new girls, and a special school was established to give instruction in the basic principles of motion economy.

Miss A. G. Shaw, who had charge of this work, explains their apprentice training program as follows:

Until recently, boys had motion economy lectures during their apprentice course. Now all trade apprentices coming into the factory go through the Motion Study School, therefore, they too have a practical grounding in motion economy. Their training is, of course, different from that of the girls as they have to use different tools and are not engaged on such routine jobs. They are taught to plan how to tackle a job themselves. For instance, they may be given a job and told to make small fixtures themselves which will enable them to use their left hand for assembling instead of merely using it as a vise. They are also taught to pre-position their tools and material to the best advantage. This encourages them to apply the principles of motion economy on any job they tackle whether it has previously been investigated or not. It stimulates them to plan their work which will be useful to the workmen of the future, particularly in a factory where the production is not all standard. They have lectures directly connected with the jobs they are doing and before they are transferred to the shops they must attain a certain standard in a test based on the principles they had been taught in the school.<sup>4</sup>

The middle-western manufacturing concern referred to on page 466 has also developed a program of training in motion study for their apprentices. These boys, all with a high school education or better, spend 60 clock-hours in a motion study training school during the period of their apprenticeship.

<sup>4</sup> A. G. Shaw, "Motion Study and Its Applications," *The Woman Engineer*, Vol. 4, No. 4, p. 59, London.



**Motion Study Training in Colleges and Universities.** Since motion and time study occupies such an important place in American industry, universities, colleges, and technical schools have, for some years, incorporated work in this field in their curricula. During the last ten or fifteen years there has been so much interest in motion and time study that many schools now have both staff and physical facilities for presenting this phase of the subject in a very satisfactory manner.<sup>5</sup> Professor David B. Porter at New York University was among the first to give such training and he has been notably successful in it.

**Motion Study Applied by Every Member of the Organization.** If the foremen, supervisors, setup men, maintenance men, tool designers, cost accountants, time study men, production-control men, and gang leaders have been trained in motion study fundamentals, they are able not only to apply them to their own particular work, but also to pass them along to the workers in the plant. And what is still more valuable, every member of the organization is available for consultation. From this large group of trained men valuable suggestions are constantly being received.

Although there are certain principles or rules of motion economy that may be applied in determining proper methods for doing a piece of work, there is no definite way of getting the most satisfactory results. Finding the best method is much like inventing or discovering something unknown. Suggestions, questions, discussions, and criticisms are all helpful. With several interested persons working on the problem, results are likely to come more quickly. Such cooperative work produces an entirely different atmosphere from the one present where the "expert" works out the method himself and puts it into effect, consulting no one and taking the full credit.

The General Electric Company was among the first organizations in this country to give motion study training to large numbers of its staff, and A. H. Mogensen was one of the first consultants in this field to advocate this practice.

**Cooperation.** The training of all members of an organization in motion and time study principles and methods tends to bring about greater cooperation between the members of the motion and time study

<sup>5</sup> Ralph M. Barnes, "The New Emphasis in Time and Motion Study," *Journal of Engineering Education*, Vol. 26, No. 3, pp. 239-248, November, 1935; also, "Motion Minds in the Making," *Factory Management and Maintenance*, Vol. 94, No. 1, pp. 19-20, January, 1936.



department and the rest of the organization. In those plants where all are not familiar with the work of this department, and particularly where motion-economy principles are not understood, there is often a resentment on the part of some foremen, supervisors, tool designers, and others when new methods are put into effect. This opposition is largely due to a lack of understanding of just what is being done and perhaps, also, to the failure of those installing the new methods to consult others associated with the work in order to get their suggestions.

There is no reason why every member of the organization might not be constantly on the lookout for better methods of doing work. And when a particular job is under consideration for improvement, all those connected with it in any way are able to contribute to, or at least understand fully, what is being undertaken. The fine cooperation that usually results when all members of an organization have been trained in the use of motion study is an important and valuable by-product of such a training program.

#### TIME STUDY TRAINING PROGRAMS

People with a knowledge of even the elementary principles of motion study are usually able to make valuable suggestions for improving methods, and consequently the training of foremen and supervisors in this field can be justified on this basis. However, only a qualified person, thoroughly trained in the fundamentals of time study, and who has served an "apprenticeship" under an experienced time study man, should be permitted to set time standards. People with only a superficial knowledge of time study should not attempt to make time studies.

**Time Study Training Programs for Top Executives, Foremen, and Supervisors.** However, a time study training program designed for top executives, foremen, and supervisors is not intended to train these men to make stop-watch time studies. Rather it is the purpose of such a training program to acquaint these people with the methods and procedures of time study so that they can assist the time study department in doing a better job. The main reasons why these groups should know how time studies are made may be listed as follows:

1. So that the planning and control department will better understand why it is important that there should be a smooth flow of



parts and materials of the proper specifications to the processing departments.

2. So that the maintenance department will realize the importance of keeping all equipment in good repair, and so that there will be a minimum of interruptions in the operation of equipment.
3. So that the inspection department will specify and maintain a definite standard of quality for each product. If quality "standards" change at frequent intervals time standards cannot be used satisfactorily.
4. So that all branches of management will be on the alert to report to the time study department any changes in methods, tools, equipment, or other factors affecting the operations on incentives. When conditions beyond the control of the operator affect an operation on incentive, the job should immediately be taken off standard and put on day work, or an equitable adjustment should be made by the time study department, so as to give the operator the same earning opportunity as formerly.
5. So that these groups will understand the importance of keeping an accurate record of work done and applying the correct time standard (or piece rate) for each job completed. Each operator must be paid for the work he turns out—no more and no less.
6. So that all members of the organization will understand the procedure of rating operator speed, and will know the meaning of normal performance.
7. So that the foreman will have the operation to be timed running smoothly before requesting that a time study be made.

**A Specific Case.** A successful time study training program for top management, foremen, and supervisors was recently conducted in a midwestern plant, and since it is perhaps typical of such programs in medium-sized manufacturing plants the program is described in some detail. This plant has a well-organized time study department, and the piece rate plan of wage incentives is used.

*Size of organization:* One plant with approximately 1000 factory employees, 60 per cent of whom are women.

*Product:* Complete line of rubber footwear.

*Wage payment plan:* (a) Hourly base rates established by job evaluation.

(b) Time standards set by time study. (Time study has been used in this plant continuously for over ten years.)

(c) Straight piece work with normal performance equal to 100 per cent efficiency. At this point the hourly day-work rate is guaranteed.



*Groups receiving training:*

Group 1—Top executives.<sup>6</sup>

Group 2—All foremen: two groups of 7 persons in each group.

Group 3—All supervisors: three groups of 5 persons in each group.

Note: Junior members of the following departments also received this training: time study, production planning and control, and pay-roll.

The sessions were approximately one and one-half hours in length, and they were held on consecutive days. The same material was presented to all three groups. All three sessions for Group 1 were completed before the Group 2 conferences were started, and they were completed before the Group 3 conferences were started. All conferences were held during the working day, either in the forenoon or the early afternoon. Meetings were held in the plant conference room with ample space and facilities for showing motion pictures and displaying charts.

The factory manager was present through all sessions of Group 1 and introduced the program to each of the other groups. He was also present at the conclusion of each session of Groups 2 and 3 and he made certain that each foreman and supervisor received complete and satisfactory answers to all his questions. In fact, the factory manager himself was familiar with every phase of time study and was fully convinced that all members of the organization should understand the detailed procedures of time study. He encouraged the foremen and supervisors to raise questions on any point that was not perfectly clear to them.

The conferences were conducted mainly by the head of the time study department with the assistance of the factory manager. An outline of the conference is given below:

*First Session*

1. Statement of the purpose of the conferences by the factory manager. Statement of benefits the company expects to receive from the conferences and the benefits the men attending the conferences should receive. General outline of the material to be covered in the conferences by the head of the time study department.
2. Showing of a 30-minute motion-picture film presenting the complete time study procedure. This film showed step by step just

<sup>6</sup> The top executive group included the factory manager, superintendent, chief chemist, chief engineer, head of production planning and control, head of cost accounting and payroll office, chief designer, head of purchasing department, and their assistants.



how a time study is made, including the calculation of the final time standard.

3. Discussion of the company Time Study Manual. This manual was read section by section, and each section was carefully explained by means of specific illustrations. (See Appendix C on page 516.)

*Second Session.* Continuation of discussion of the time study manual. An actual job from the plant was brought into the conference room and demonstrated to the group. The time study of this job (see Fig. 252) which had previously been made had been transferred to a large wall chart 4 feet by 8 feet in size and to a computation sheet 4 feet by 8 feet in size (see Fig. 254). These charts were hung in the front of the conference room. Each item on the time study sheet and on the computation sheet was explained to the group. This explanation led to the final establishment of the time standard for the job and then to the determination of the piece rate for it. Finally an explanation was made as to how the piece rate was put into effect.

*Third Session.* The first part of this session was devoted to a definition of "normal operator performance" as it pertained to this plant. Then each person was shown the introductory reel of the Barnes Work Measurement Film; after this each person rated ten different walking speeds as well as a film of several different factory operations. There was a general discussion of the meaning of "100 per cent performance." The importance of the foremen and supervisors being able to evaluate operator speed accurately was emphasized.

There was a discussion of the relationship between the earnings of operators and their efficiencies above and below 100 per cent performance. The number of people who might be expected to attain efficiencies in the range of 125 to 150 per cent of normal was also discussed. The importance of accurately reporting work done was emphasized.

The entire time study procedure was reviewed in light of just how it affected the foremen or supervisor in the particular group. There was a question and discussion period, with the factory manager and the head of the time study department both participating.

After the conferences for the three groups had been completed, the factory manager and the head of time study held a two-hour conference with the president of the union and the shop steward. The same material, in somewhat condensed form, was presented to these men. This session was followed by several discussion periods.



*Follow-up.* This series of three conferences was followed each month with a one-hour conference for Groups 2 and 3, at which time a review of current problems pertaining to time standards and wages was made and each person was given the opportunity of making ratings of motion picture films of factory operations for which known standards were available. Actual factory operations were also rated.

This company owns its own motion-picture camera, projector, screen, and auxiliary equipment for making and showing 16-mm. films.

**Time Study Training for Industrial Engineers from Several Plants of the Same Organization.** Even though time study men may be doing accurate and consistent work in a given plant, if a company operates several plants, it is good policy to standardize the time study procedure for all plants. This is especially desirable if identical operations are performed in two or more plants, if time study men are frequently transferred from one plant to another, if labor cost comparisons are made between plants, and if company-wide standard data are to be developed and used most effectively.

There is merit in having time study procedures so standardized and time study men so trained that, if all time study men in all plants of a company were simultaneously to time the same operation independently, they would all establish essentially the same time standard for the job. Because the standardization of time study procedure and the training of time study men in this procedure are of growing importance, an actual case will be presented to show how a group of time study men were trained in one organization.

**A Specific Case.** The following case illustrates what may be accomplished through a systematic attempt to improve time study procedures. The company referred to here has five plants in four different midwestern states and employs a total of some 10,000 people. The company has been in business many years and has used time study in all plants for a long time. Prior to the inauguration of the Time Study Conferences each plant had its own time study procedure, and there was almost no exchange of information in this area between the plants. As might be expected, the time study methods differed, not all the forms used were alike, and there was considerable variation in time standards for identical jobs performed in the several plants.

Top management had received complaints from plant managers and from union officers about the variation in time standards, and a survey of time study procedures in all plants confirmed this point. Management decided to develop and standardize time study procedures that would best serve their needs, and a plan was inaugurated to have the



time study men themselves, under the guidance of an able executive of the company, solve their own problems. The plan took the form of two-day Time Study Conferences which were held at approximately two-month intervals.

The first conference was attended by the chief time study man and two or three of his assistants from each of the five plants. Time study

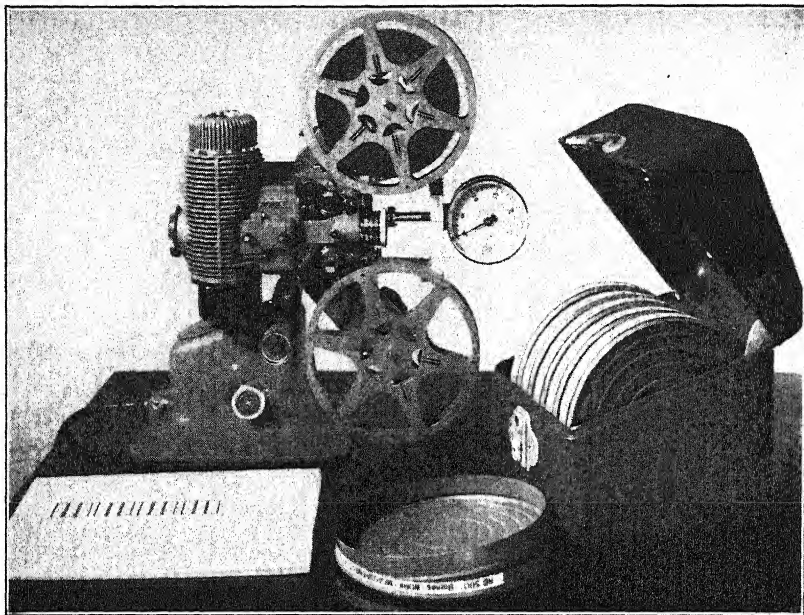


FIG. 286. Silent motion-picture projector (16-mm.) with a tachometer attached. This projector is suitable for showing rating films and time study training films.

methods used in each plant were described and criticized. Everyday operating problems were presented by each person and discussed. The group agreed that they should work toward a standardized time study procedure and that they should adopt the best time study practices available. A new time study form was designed, and the problem of performance rating was considered. At succeeding conferences, the following subjects were discussed: methods of timing, the determination and application of allowances, waiting time, the development of a performance rating procedure for the company, all-day time studies, a "methods development program" for training foremen in all plants, the development of standard data for common operations in all plants, and other related subjects.



The rating of walking, of dealing cards, and of films of factory operations was a part of each conference. Also, during conferences 3 to 7, several actual factory operations were timed. Each time study man, independently, made a time study of each operation. The man was given ample time to work up his data and to determine the time standard in the same way he ordinarily did this in his own plant. The completed time studies were immediately submitted to the chairman of the conference, and a summary was prepared similar to that shown in Fig. 288. The time studies were then returned to the time study men for use in the discussion which followed.

After all time study data were tabulated, the conference leader read off the values for each of the seven items without mentioning from whose time study the values had been taken. Then there was a general discussion of the variations and the probable reason for the variations. After the discussion of a particular study was completed, the original time studies were turned in to the conference leader. Later these studies were reproduced, bound together, and a copy of the complete set of time studies was given each man for his file.

Several factors contributed to the success of the program described above. Among them the following seem to be the most important:

1. Top management was in complete sympathy with the program and was determined that the company should make use of the best time study techniques known.
2. A capable man (the assistant to the vice-president in charge of production) was selected to direct the program. It was his belief that time study men from all plants should assist in working out the details of the program rather than that the program should be developed in the main office. It was felt that the training each man would receive in the process of developing the new time study procedure would be very valuable to the man.
3. Each time study man was made to see the merits of having a standardized time study procedure for all plants, and each man contributed to the development of a workable system. Incidentally, at the suggestion of the time study men themselves the program has now expanded to include such things as determination of allowances, analysis of down-time, development of a "methods improvement program for foremen and supervisors," and the determination of standard data for use in all plants.
4. The plant managers and other executives in the organization were interested in the details of the program and kept themselves in-



formed as to the progress that was being made. The president and the vice-president of the company on several occasions attended the Time Study Conferences and took part in them.

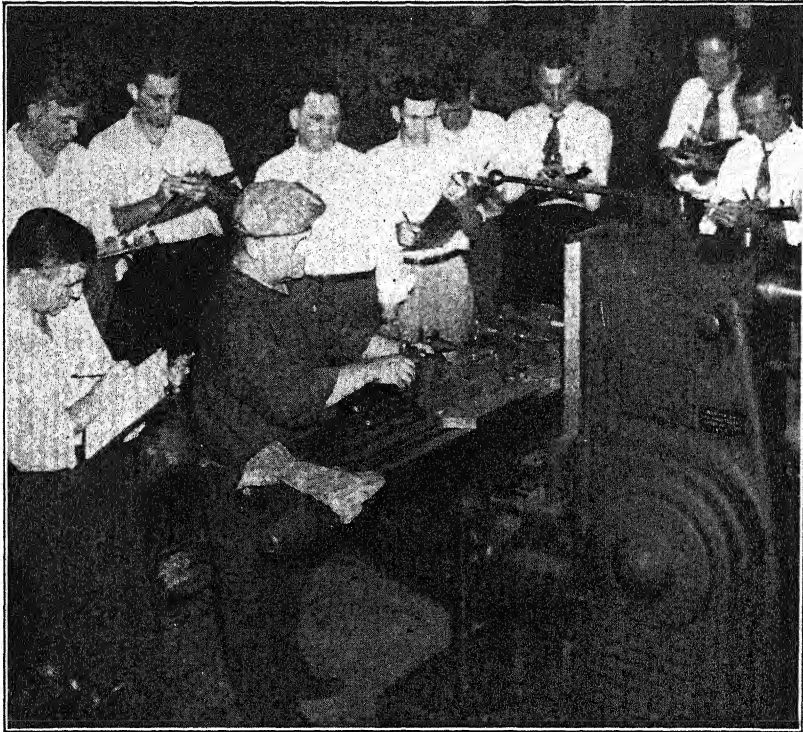


FIG. 287. Group of time study men making a simultaneous time study in the machine shop. The results of such a study may be tabulated in a manner similar to that shown in Fig. 288.

5. A bound, stencil-duplicated volume of proceedings, prepared after each time study conference, served as a progress report. A copy went to the vice-president in charge of production and to other executives, as well as to each time study man. A reproduction of every time study made during the conference (but omitting the time study man's name) was included in the volume, as well as summary sheets similar to Fig. 288. These reports have been successfully used by the management in discussing with the union the ability of time study men to determine accurate, consistent, and fair standards.



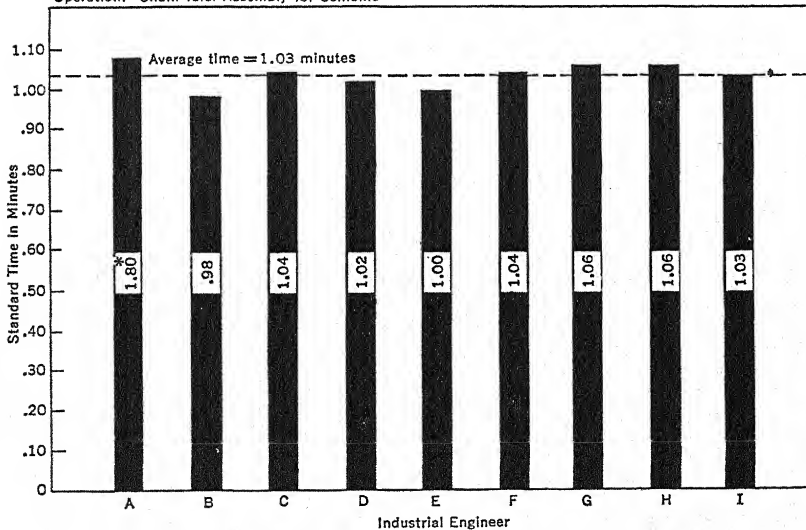
# Results of a Simultaneous Time Study Made by a Group of Time Study Men. There has been much speculation about the variation

## RESULT SHEET

Operation: Chain Idler Assembly for Combine

Information from Time Study	Industrial Engineer Who Made Study									Average
	A	B	C	D	E	F	G	H	I	
1. Number of elements	9	7	9	10	9	8	11	8	13	9
2. Performance rating factor	110	105	105	105	100	105	110	110	110	107
3. Personal allowance in per cent	5	3	3	3	5	5	5	5	3	4
4. Delay allowance in per cent	2	2	3	2	2	2	2	2	2	2
5. Fatigue allowance in per cent	2	4	2	5	5	2	3	4	3	3
6. Total allowances in per cent	9	9	8	10	12	9	10	11	8	10
7. Total standard time in minutes	1.08	.98	1.04	1.02	1.00	1.04	1.06	1.06	1.03	1.03

Operation: Chain Idler Assembly for Combine



\*The number on the bar represents the standard time in minutes for the operation.

FIG. 288. Table and chart showing the results of a simultaneous time study made by nine different industrial engineers from five different plants.

that would be found in time standards set by a group of time study men if they were to study the same operation at the same time.

As a part of each Time Study Conference already referred to, the time study men made time studies of actual factory operations. An experienced operator performed the job, and each time study man



made his time study in his accustomed way. Figure 288 shows the summary of one of the best studies made by this group at the seventh Time Study Conference. Assembling a chain idler for a combine was the operation studied. Time study man B set a low time standard of 0.98 minute and A set a high standard of 1.08 minutes on this job. The average of the nine time study men was 1.03 minutes. B was 5 per cent lower and A was 5 per cent higher than the average of the group. All time standards fell within plus or minus 5 per cent of the average for the group. Although it seems certain that these men will further improve their ability to set accurate and consistent time standards with more practice and experience, it might be added that the record of these men as shown in Fig. 288 is perhaps as good as will be found among time study men in general. These men worked in five different plants, and only two men had seen the operation before they studied it.

It should also be noted that the average performance rating factor for the nine men was 107 per cent, with E using the lowest factor of 100, and A, G, H, and I using the highest factor of 110 per cent. E was 7 per cent low, and A, G, H, and I were 3 per cent high.

The total allowances varied from a low of 8 per cent to a high of 12 per cent, with an average of 10 per cent.

**Training in Rating Operator Performance.** Practice in the rating of walking and the rating of dealing cards serves to show the importance of performance rating in time study work. Such rating studies may well be included in all time study training programs. These studies are also excellent for training beginning time study men and for improving the rating ability of experienced industrial engineers. The rating of walking and dealing cards is so widely used in industry that suggestions for making rating studies of these two activities are given on pages 534 and 537.

Rating of other simple operations such as filling pin board (see Figs. 65 and 66), tossing blocks, and assembling small parts is also recommended. A motion-picture film of an actual factory operation may be formed into a continuous loop and projected at constant speed for rating purposes.

Considerable use is being made of such film loops for practice in rating and for time study training purposes. Stop-watch time studies can be made of operations on the screen and standards can be established. Some companies have a library of such films for training purposes and to serve as standards on their important operations.



Figure 236 on page 336 shows a motor-driven camera for making such motion pictures, and Fig. 286 shows a 16-mm. projector equipped with a tachometer for showing such films.

**Effect of Practice on Accuracy of Rating.** In order to measure the variations in ratings made by experienced time study men over a long period, Eli Lilly and Company repeated the walking study and the card dealing study each week for a period of four months. The results shown in Figs. 289 and 290 are as follows: for walking the systematic error was reduced from  $-13.7$  to  $-2.3$  and the mean deviation from  $7.6$  to  $2.4$ , whereas, for card dealing, the systematic error was reduced from  $+1.8$  to  $+0.8$ , and the mean deviation from  $6.2$  to  $2.4$ .

**Work Measurement Project.** During the past two years some 5000 people from over 350 different industries in the United States and Canada have rated motion-picture films of typical factory operations as a part of a study conducted by the author. All the films were projected at a constant speed, and the person viewing the film rated the operator's tempo in per cent. Each person's ratings were returned, and these data were analyzed using a standardized statistical procedure.<sup>7</sup>

These work measurement studies would seem to indicate that:

1. An individual's accuracy and consistency in performance rating can be improved through proper training.
2. An individual can rate more accurately on performances that are close to normal. There is some tendency to rate too high on slow working speeds and too low on working speeds that are considerably above normal.
3. On operations such as walking, card dealing, and other tasks consisting largely of unrestricted motions, the ordinary person can be trained to rate within plus or minus 5 per cent of the actual rating. A group of experienced time study men in a plant can set time standards for an operation no "standard" of which will vary more than plus or minus 5 to 7 per cent from the average for the group. That is, no one time standard should differ more than 10 to 15 per cent from any other. Figure 288 on page 477 shows an actual case.
4. On simple work (free and unrestricted motions) a person can rate a motion-picture film of an operation about as accurately as the operation itself.<sup>8</sup>

<sup>7</sup> "Work Measurement Manual," 3rd ed., pp. 81-87.

<sup>8</sup> *Ibid.*, p. 91.



## RESULT SHEET - GRAPHICAL ANALYSIS

Operation: Film of Dealing Cards - Feb. 16 and 23, 1945

Date of Original Experiment: Feb. 16, 1945

Actual Dealing Cards - May 4 through Aug. 24, 1945

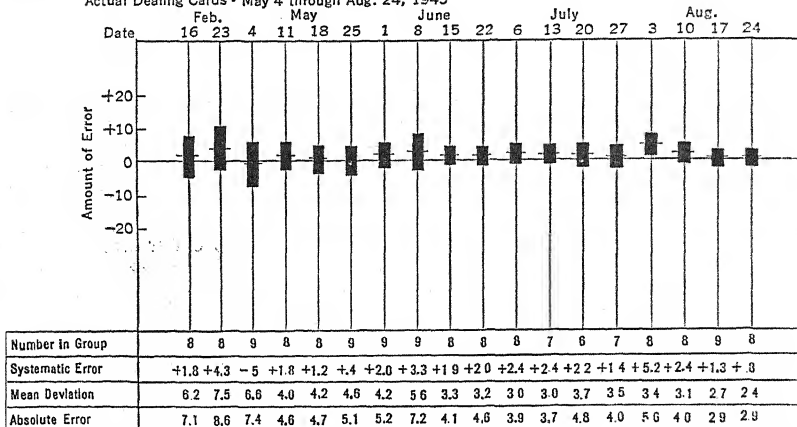


Fig. 289. Chart showing the improvement in rating over a four-month period. This group of time study men rated a film of walking on February 16 and on February 23, and then rated actual walking during the remainder of the period. Study made by Methods and Standards Department, Eli Lilly and Company.

## RESULT SHEET - GRAPHICAL ANALYSIS

Operation: Film of Walking - Feb. 16 and 23, 1945

Date of Original Experiment: Feb. 16, 1945

Actual Walking - May 4 through Aug. 24, 1945

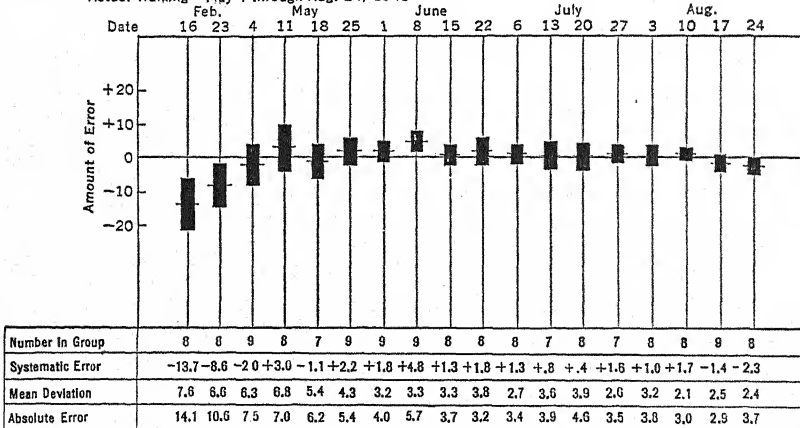


Fig. 290. Chart showing the improvement in rating over a four-month period. This group of time study men rated a film of card dealing on February 16 and on February 23, and then rated actual card dealing during the remainder of the period. Study made by Methods and Standards Department, Eli Lilly and Company.



5. Motion picture films serve a valuable purpose for training individuals in performance rating. They also may be used to assist in acquainting top management, foremen, supervisors, and workers with time study technique. A library of films showing operators working at normal tempo and at known speeds above and below normal, can serve as standards or bench marks for time study work in a plant.
6. Periodic time study conferences or clinics within a company at which all phases of time study practices are discussed are needed to keep a time study department functioning satisfactorily. Practice in making simultaneous time studies of actual factory jobs should be a part of such conferences.



## CHAPTER 29

### TRAINING THE OPERATOR—EFFECT OF PRACTICE

It is not the purpose here to discuss the broad field of employee training but rather to present some specific methods that have been found useful in training operators to do a particular job. Such training is usually given by the supervisory force although the motion and time study analyst or a special instructor may handle this work.

Although we often have pictured for us large groups of workers performing identical routine operations over long periods, actually this is not the typical situation even in large plants. Not only does the worker normally perform many different operations in the course of a month but with constant changes in methods, with improvements in materials, and with the rapid introduction of new models, there is a never-ending succession of new jobs which the operator must learn. It seems that the worker today, more than ever before, must be able to do a variety of work, which tends to increase the amount of training required in industry.

**Training Methods on Simple Operations.** The best method imaginable for doing a given task is of little value unless the operator can and will do the work in the prescribed manner. Where one or a very few persons are employed on a given job and where the work is relatively simple, the ordinary instruction sheet forms an excellent guide for training the operator. Also, on semi-skilled work where the worker is familiar with the operation of the machine but needs instructions for the performance of particular operations, the simple instruction sheet is satisfactory. For example, the one shown in Fig. 291 not only gives a written description of the elements required for turning the gear blank but the drawing at the top of the sheet also shows the exact location of the tools and of the parts to be machined. The time value for each element is also included as well as the total standard time for the operation.

Where the work is entirely manual, instructions prepared on the order of the operation chart shown in Fig. 52 on page 77 are of value in that they indicate exactly what hand motions are required and show the layout of the work place as well.



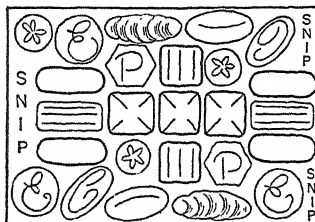
INSTRUCTION SHEET							
Part Name <u>Spur gear</u> Case <u>D</u>				Customer <u>Amer. Tool Co.</u>			
Operation Name <u>Drill, rough one side and <math>\frac{1}{2}</math> of outside diameter</u>				Part No. <u>1073 A-F</u>			
Dept. <u>11</u> Machine class, <u>58</u> Machine name, <u>Jones &amp; Lamson</u>				Operation No. <u>5 TR.</u>			
Made by <u>S. R. K.</u> Approved by <u>S. M.</u> Date <u>7-9-47</u> Mat'l <u>SAE2315</u>							
Tool layout							
Set-up Time: New set-up 60.00 Change of size 30.00							
No.	Procedure	Tools—jigs, etc.	Speed		Feed		Base time
			Set- ting min.	Ft./ min.	Set- ting In./ rev.		
1	Pick up and chuck 2 pieces.....						0.12
2	Start machine and true up (if necessary).....						0.10
3	Change speed.....						0.03
4	Adv. turret and throw in feed.....						0.06
5	ROUGH OUTSIDE DIAMETER ( $\frac{3}{4}$ ).....	A. $\frac{3}{4} \times 1\frac{1}{4}$ in. tools.....		70	71	0.014	2.32
6	Back turret and index.....						0.07
7	Advance turret, set headstock, throw in feed and change speed.....						0.12
8	DRILL.....	B. $1\frac{3}{16}$ in. drills.....		63	71	0.014	0.58
9	Back turret and index.....						0.07
10	Advance turret and lock.....						0.08
11	Advance headstock, change speed and throw in feed.....						0.08
12	ROUGH FACE 1 SIDE.....	C. $\frac{3}{4} \times 1\frac{1}{4}$ in. tools.....		70	71	0.014	1.65
13	ROUGH FACE HUB.....	D. $\frac{3}{4} \times 1\frac{1}{4}$ in. tools.....		30	71	0.014	
14	Unlock, back and index turret.....						0.07
15	Advance turret and set head stock.....						0.09
16	CHAMFER INSIDE FLANGE.....	E. $\frac{3}{4} \times 1\frac{1}{4}$ in. Form tools.....		70	Hand		0.10
17	Advance head stock.....						0.06
18	CHAMFER HUB.....	E. $\frac{3}{4} \times 1\frac{1}{4}$ in. Form tools.....		30	Hand		0.10
19	Back turret and index.....						0.07
20	Set head stock.....						0.12
21	Stop machine.....						0.03
22	Loosen and remove 2 pieces.....						0.10
	Total handling time for two pieces.....						1.47
	Total machine time for two pieces.....						4.55
	Total base time for two pieces.....						6.02
	Total base time for one piece.....						3.01
	Allowances 10 per cent.....						0.30
	Standard time in minutes per piece.....						3.31

FIG. 291. Instruction sheet for turret lathe operation. Size  $8\frac{1}{2} \times 11$  inches.



# ½ LB. BLUE RIBBON BOX (FLANGE) LIST No. 4623-12

Cups	Unit No.	Name	Cups	Unit No.	Name
Round	203	Raspberry Cup	Round	376	Caramelized Brazil
"	204	Apricot Cup	"	392	Croquante Whirl
"	221	Strawberry Creme	"	393	Vanilla Caramel
"	275	Coffee Creme	"	394	Marzipan Sandwich
"	371	Orange Marzipan	"	396	Tosca Pate



Heavy lines  
= Foil Covered  
Units

Make weight with Accommodation Units, one less than weight of last Chocolate.

If Light Add: 1 Croquante Whirl, 1 Apricot Cup:

If Heavy Take Out: 1 Apricot Cup.

	No.		Patt. No.	Paper No.
Linings (Center) (Emb. E.				
Foil.....	1	13, $\frac{3}{8}$ × 6, $\frac{7}{8}$	Shaped	8795
(Ends).....	2	4, $\frac{7}{8}$ × 2, $\frac{15}{16}$	3226	8796
Top-Pad.....	1	6, $\frac{13}{16}$ × 4, $\frac{13}{16}$	....	4990
Stock No. 04990—				
To be cleared first				
Cups (Round).....	25		....	3569
Wrap.....	1	14, $\frac{13}{16}$ × 11, $\frac{1}{8}$	2716	142
Wrap fastened on bottom				
with Gloy, ends folded				
and fastened on bottom				
with Gloy.				
Printed Identification Key.	1	8, $\frac{3}{4}$ × 6, $\frac{1}{8}$	....	5070

Snip—Brown.

Filled on Printed Identification.

Tear-off Price Seal (Stk. No. 2878) on wrap, top-left.

Foil (Stock No. 8666) Blue and Silver E. Design—to be used when Stk. No. 08666 is cleared.

## FOILS

Stock No. 08666—Blue Printing on Silver. Width of Reel 3" for Tosca Pate, Marzipan Sandwich and Strawberry Creme.

Symbol No. F. 136.

Outer No. R. 976—Packed ¼ dozen.

Outer tied String—Single.

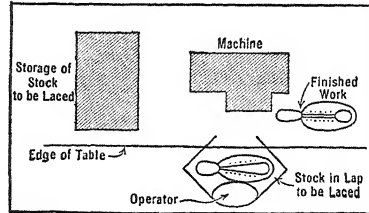
New Lines Office

First packing to be sent to Inspection Office.  
Issued to Inspection Office from New Lines Office.

FIG. 292. Instruction sheet for packing chocolates. Size 8½ × 11 inches.



OPERATION: Lacing  
 TYPES: L.T.T.—S.U.  
 DETAIL: 1 Spindle  
 MACHINE: Ensign  
 CODE: No. 52



Sketch of Layout



Get next upper like this, first finger of left hand between eyelet edges.



Lift upper from stack with left hand, inserting second, third, and fourth fingers in top of shoe. Insert first finger of left hand between eyelet edges.



Line up eyelet edges by moving hands in opposite directions and closing eyelet edges together.



Get top end of eyelet edges between thumb and first finger of right hand. Move first finger of left hand out from between eyelet edges and grasp edges like this.



Position fifth eyelet over spindle.



Pull upper down onto spindle.



Press down pedal to start machine and move fingers to this position.



Hold upper while being laced. As spindle is automatically removed, upper is moved up and slightly to right while machine ties knot and cuts thread. Laced upper is finished in this position.



Move finished upper to a position over stack of finished uppers.



Place finished upper on stack.

Repeat Cycle.

FIG. 293. Pictorial instruction sheet for lacing tennis shoes.



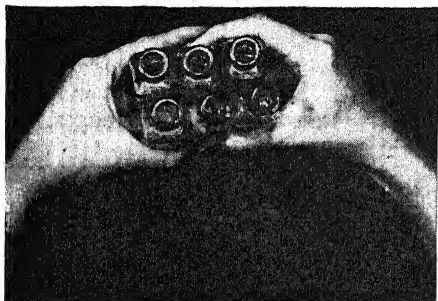
## OPERATION PROCEDURE FOR HANDLING AND INSPECTION OF BOTTLES



### 1. Pick up bottles (2 rows of 3).

Grasp 6 bottles (2 in left hand, 4 in right hand). Hold thumbs toward you and fingers away from you.

---



### 2. Inspect necks.

Tilt necks slightly so that the light will show defects.

---



### 3. Separate bottles.

Separate bottles so that the left hand holds 2 and the right hand 4.

---

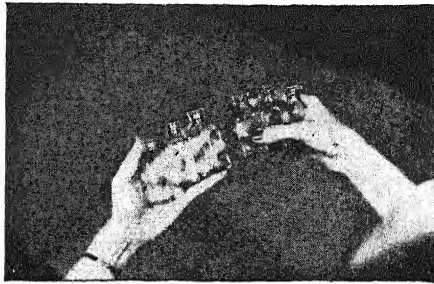


- ### 4. Turn left wrist to left with palm of hand up. At the same time move the left thumb toward the left so that the top bottle falls into place to the left of the bottom bottle. This places 2 bottles in the palm ready for inspection. Use the left thumb as a stop.
- 

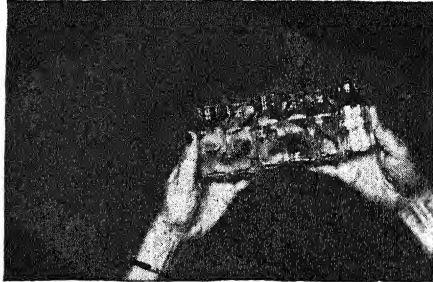
FIG. 294. Pictorial instruction sheet for inspection



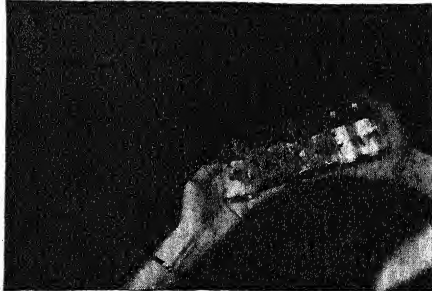
5. Lower upper left bottle in right hand to the fingers of left hand. To do this, tilt both hands slightly to the left, raise the right thumb, and let bottle slide to tips of fingers of left hand. (Keep hands together so that tips of fingers are touching. This prevents bottles from falling.)



6. Lower upper right bottle to palm of right hand. Slide right thumb to the right, pushing bottle into place to right of all bottles.



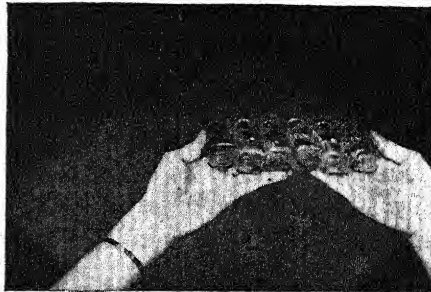
7. Line up bottles on tips of fingers and shift bottles toward right thumb as a guide. (Keep bottles tight together to shift more easily.)



8. To inspect sides, roll bottles one-fourth turn. Four bottles are in the right hand, the fifth bottle is on the tips of the fingers just ready to fall. With the left thumb turn the left bottle one-fourth turn to the left. Hold the thumb as a guide. Tilt both hands to left so that bottles roll one-fourth turn, one at a time.

9. Repeat steps 7 and 8 so that you can inspect the other side of the bottles.

10. Inspect bases and pack neck down in cartons. Keep all bottles tight together between thumbs, inspect bases, and slide between partitions. Make sure that carton is filled with bottles.



of bottles. One-ounce French squares.



Another case is taken from a chocolate factory. When a new box or a new assortment of chocolates is to be packed the pattern is determined, and then the operators are required to pack by this pattern. The customary procedure was to send a sample package to the supervisor, along with the order for packing. Very often the first order was a rush one, and a number of operators were put on packing at once. In order for the operators to begin work the supervisor had to pack a sample box for each of them, often having the girls standing around waiting while this was being done. The use of an instruction sheet similar to that shown in Fig. 292 prepared in advance, and reproduced by hectograph, has not only saved the operators waiting time but has also enabled them to bring their packing speed up to standard in a very short time.

**Pictorial Instruction Sheets.** The use of still pictures in connection with written instructions, as shown in Figs. 293 and 294, has proved very effective in supplementing the efforts of the instructor in training operators in a rubber footwear plant<sup>1</sup> and a glass plant. After glass bottles are made they must be inspected for defects. The handling and inspection of bottles require considerable time to learn, and there is a knack to doing the job. The instruction sheet shown in Fig. 294 was developed by the Training Department of the Armstrong Cork Company to show the key points. The instruction sheet is supplemented by a motion picture showing an experienced operator inspecting bottles. Several different sizes and shapes of bottles are included, and some slow-motion shots are used to illustrate the position of the hands in grasping and turning the bottles.

It seems that much of the skill required in doing some kinds of manual work centers around the exact way certain motions are performed, particularly grasp, hold, position, and pre-position. It appears that the transport and use motions require less attention and are more easily taught. In other words, it is more useful to show the operator how to take hold of the object previous to moving it, and how to position it before releasing it, than it is to show actually the transportation or movement of the object.

Another example of the usefulness of still pictures is given in Figs. 137 and 138 on pages 222 and 223 showing how the operator grasps the bone and how she positions it at the beginning of the creasing motion in folding paper.

<sup>1</sup> A. Williams, "Teach It with Pictures," *Factory Management and Maintenance*, Vol. 94, No. 12, pp. 50-51, December, 1936.



**Training Assembly Operators.** The following is a detailed description of the procedure that was followed in training a group of ten operators to perform a short-cycle assembly operation. This opera-

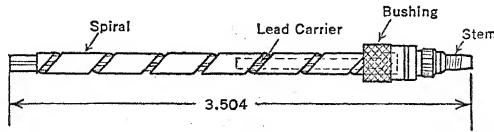


FIG. 295. Mechanism assembly.

tion consisted of placing four small parts together using both hands and the eyes. Figure 295 is a drawing of the finished mechanism assembly. The new operation was a combination of two old operations, which will be referred to as the superseded operations. Figure 296



FIG. 296. Mechanism assembly operation—arrangement of work place.

shows the arrangement of the work place. The only special equipment needed was a steel plate containing a small V-block to hold the lead carrier while it was placed into the stem of the assembly.



The improved method, which, incidentally, saved over 13,000 man hours of direct labor per year, was developed by L. F. Youde. He describes<sup>2</sup> the training procedure which he used in the following way:

After the V-block was made for the new operation, the motion study analyst proceeded to run the new operation for approximately four hours in the methods laboratory. This trial run was made for the following reasons: (1) To test the equipment and eliminate any "bugs" that were present. This is important, as equipment should be fully tested before an operator is placed in training on the job. (2) To check the movements and establish a synthetic time standard for the operation from standard data. (3) To make certain that the motion study analyst who was to act as the trainer, was able to perform the new operation with the correct movements.

The procedure described below was used to train the first operator on the new job.

(1) The new operation was shown and explained in general terms to the operator. Since she had been working on one of the superseded operations, she was told that her old job was being combined with another job so as to make a more efficient operation. Also, that the change was part of the regular methods improvement program. Other operations in her department that had been improved were pointed out to her as examples of the program. Because this operator had been on one of the superseded operations, it was not necessary to describe to her where the assembly was used.

(2) The operator was told what the time standard was on the new operation and that after a period of training she would be placed on piece work.

(3) With the operator standing slightly to his left and rear, the trainer demonstrated the new operation as follows:

(a) For 20 cycles the trainer performed the operation quite rapidly in order to give the operator an over-all picture of the new job.

(b) For 20 cycles the trainer performed quite slowly in order to give the operator a picture of the "gets" and "places" and the hand that performed them.

(c) For 10 cycles the trainer explained and performed slowly each of the "gets" and "places" in the operation. The explanation consisted of telling the operator where the eyes were used, which fingers were used in getting different parts, and how the parts were placed together. In running 10 cycles, each explanation was repeated 10 times. This repetition helped the operator retain more of the instructions than if only one cycle had been explained.

(4) The operator was seated at the work place and she was asked to perform the operation slowly the first day or two. She was told that at first the output was not important—that it was more important that she learn the correct methods, and that the speed would come naturally later.

<sup>2</sup> L. F. Youde, "A Study of the Training Time for Two Repetitive Operations," Theses, University of Iowa, 1947.



(5) The operator was then told to go ahead and start performing the operation. The operator's performance as to the correct movements was checked as follows:

(a) The trainer watched the operator for her first ten minutes on the job to be sure she had the right idea and to correct any very bad errors.

(b) The operator was allowed to run one hour to get the feel of the operation and its parts.

(c) During the remainder of the operator's first day on the job, the trainer checked her once every hour to change any incorrect movements before they became a habit.

(d) During the second and third days, the trainer checked the operator once every two hours.

(e) For the remainder of the time until the operator reached standard time and was placed on piece work, the trainer checked twice a day. The amount of checking varied among the different operators trained on the new operation. Figure 297 shows the learning curve for the first operator on this job.

The other operators were trained in exactly the same way as the first one, except that their training was done on the production floor instead of in the methods laboratory.

**Training Methods on Complex Operations.** There are some operations that are complex in nature, and the operator may require considerable skill to perform them satisfactorily. A much longer training period is ordinarily required for this type of work than for simpler operations.

Where a sizable group of employees is engaged on such work there is an opportunity for a more elaborate training program. Some companies find it profitable under such conditions to establish a vestibule training school or a separate training department apart from the regular production departments.

With over 100 operators on the semi-automatic lathe operation described on page 19, the company established a special school for training new operators for this work. Whereas it formerly took 6 months to train these operators it now requires but 6 to 8 weeks.

To cite another case<sup>3</sup> of group training on complex operations, L. P. Persing of the Fort Wayne works of the General Electric Company supervised the training of 200 new operators hired for a rush job of assembling large numbers of extremely delicate parts required in the manufacture of electric meters.

The entire assembly process was broken down into small assemblies, which were studied in order to determine the best way of making

<sup>3</sup> L. P. Persing, "Motion Study—The Teacher," *Factory and Industrial Management*, Vol. 83, No. 9, pp. 337-340.



these subassemblies. Where special trays, fixtures, and combination tools were required, they were built and the correct layout of the work place was arranged. One operator was trained by the instructor and, after she became proficient in the new method, motion pictures were made of the operation so they might be used in the training of the other operators.

It was found practicable to train eighteen operators at one time. The training of this group was carried out in the following way. Eighteen duplicate sets of trays and tools were installed in exactly the same way on tables in the motion study laboratory (see Fig. 70 on page 116). All the operators were seated at these tables facing the motion-picture screen at the front of the room. A general explanation of the operation was made and instructions were given in the care that should be exercised in handling the parts so that the finish would not be marred or intricate and delicate parts damaged during the assembly operation. The motion pictures of the operation were then projected several times on the screen, both forward and backward, and at reduced speed so that the new operators could see the correct way of doing the work. With the projector running very slowly the instructor pointed out the correct way of grasping, carrying, positioning the parts, and of performing each of the other motions of the cycle. There were two instructors: one operated the projector and explained the motions, and the other, an experienced operator, gave individual instruction and inspected the work for the group.

By employing the ordinary method of using an experienced operator to train one or two new operators on the production floor the experienced operator produced but 40 to 50 per cent of her normal output. Also this method of training required an exceedingly long training period. Using the new method, two instructors trained eighteen new operators in a separate room where there was no interference with the regular manufacturing operations. At the end of one week of training, the eighteen operators were transferred to the production floor properly trained for their task. This was but one-third the time required for training new operators by the old method.

Mr. Persing gives the following reasons why they prefer to train the operators in a separate room: <sup>4</sup>

1. We could get 100 per cent attention. There was not the confusion and noise of other activities to distract the operator's attention such as you have on the average manufacturing floor.

<sup>4</sup> *Ibid.*, p. 339.



2. The operator does not get as nervous when trained in a separate room. There are not a lot of other workers watching the instructor teach the new cycle of motions, which in general are a great deal different from those they have seen before, and the layout of the trays is a curiosity.
3. When any problem came up that was of interest to all the operators, you could get their attention at once and explain how to overcome or correct the fault.
4. As the operators on this particular operation were to be taught the cycle of motions by watching the experienced operator assemble the register on the moving-picture screen, it was necessary that the room be in semi-darkness.

The Colonial Radio Corporation was one of the first radio manufacturers to successfully operate a school for training new assembly operators. All girls at the time of employment were given two to three days' training in a separate room under the supervision of a competent instructor.

The class room contained assembly benches with jigs, fixtures, hand tools, and the necessary parts and bins to handle such typical factory operations as screwdriver work, assembly and bench work with pliers, and soldering operations. Groups of 8 to 12, and never more than 15, were trained at a time. The girls were paid their regular hourly base wage during the training period. At the beginning of the training period a simple explanation of the purpose of the course was given to the group. Extracts from this explanation are given below:

As you are probably aware, the purpose of this class is to teach a better way of performing some of our more common assembly operations which involve such familiar parts as nuts, screws, lockwashers, wires, condensers, resistors, etc.

All of us realize the fact that certain ways of doing a thing are better than others. It has been established that there is a best way of performing any given act, and we have also made the discovery, which most of you have probably known all along, that the best way is almost invariably, also, the easiest way. Haven't you found this to be the case in your experience?

Just as you in your home attempt to find the best way of performing your household duties, so, in industry, we attempt to find the best way of doing the things required of us.

It has been established that at least 25 per cent of the motions used by the average employee in the average factory operations are wasted motions. These wasted motions are needless motions which contribute only one thing as far as the operator or the operation is concerned, and that is fatigue.

Naturally you may ask—"What is the purpose of finding the best and easiest way of performing operations in the plant?" This can be stated briefly as follows:

"It is the desire on the part of Colonial to build a better radio set at a lower cost without, however, requiring the expenditure of any more physical effort on the part of those of us directly engaged in building them."



All of you realize the amount of work we have in our plant depends on the number of radio sets the Sales Organization of the Colonial Radio Company can sell. When you and I, and millions of other consumers, decide to buy a radio set, or any other merchandise, we always attempt to get the best product we can for the money we want to spend, and, if the best radio set we can buy for a given sum of money happens to be a Colonial radio, we will buy it. In other words, the welfare of the Colonial Radio Corporation and, coincidentally in a large measure, all of us, depends on the ability of Colonial to build at least as good a set as any other manufacturer at the same or at a lower price.

After the above explanation has been made and any questions by members of the class have been discussed, the group is given a simple assembly operation to perform. An explanation is given of what the finished job must be like, and then each person is allowed to do the task in any way that she wishes. Each girl is given a timer and pencil and paper to record the time for making ten assemblies.

She continues to do this task for an hour, recording the time for each set of ten assemblies.

Then an assembly fixture and improved bins are given to the operator. The proper arrangement of the work place is made, and the girl is carefully instructed in the proper method of doing the work. An explanation is also given of the principles of motion economy employed and why the new method is easier, faster and safer than the old one.

After the girl understands how to do the task in the proper way, she again works for an hour or so, timing herself for groups of ten pieces and recording the time as before.

The fact that the improved method saves time is obvious to her since she has set her own pace and read and recorded her own time. She is well aware that motion study is not a "speed up" but that it enables her to do more work with less fatigue.

After the new girl has worked on a simple assembly operation, she is given other jobs that are typical of those she will see in the factory and perhaps some of which she will work on after the training period is over.

Although the main purpose of the school is to train new operators in the principles of motion economy, Colonial has found that the school also serves another very important function. It shows the employees in a most convincing manner that improving methods of doing work is for their benefit as well as for the company's and that actually the best way from a motion study angle is invariably the least fatiguing way and the most satisfactory way in every respect for the operator.



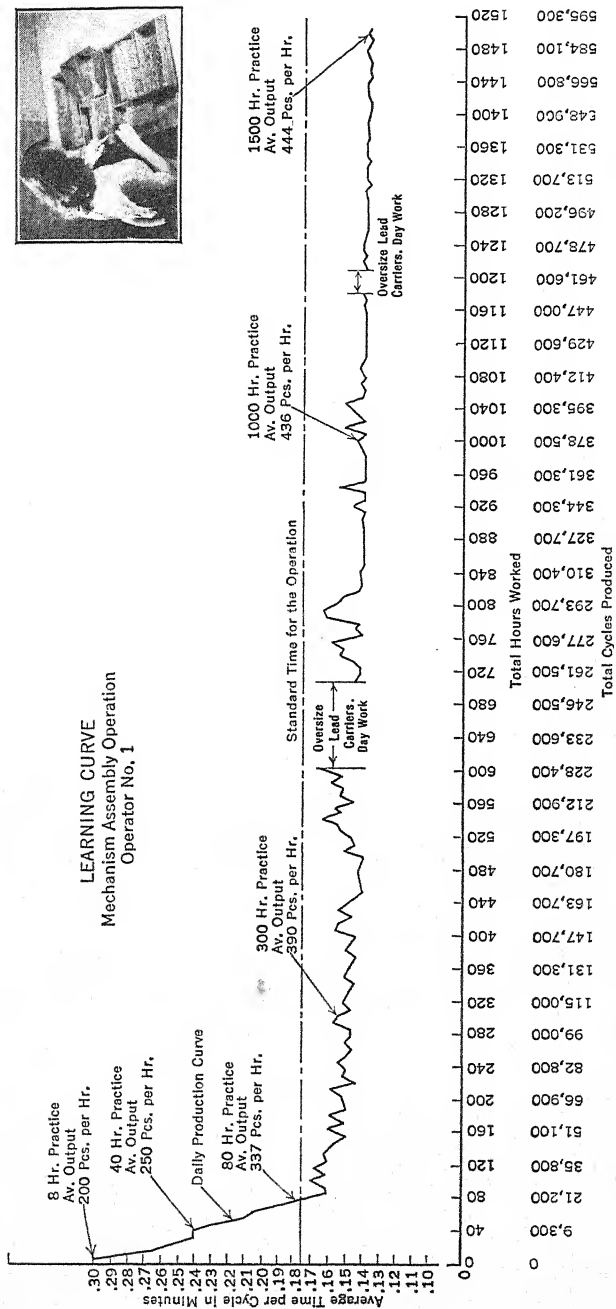


Fig. 297. Learning curve for mechanism assembly operation. The average hourly output for the first day was 200 pieces. After 590,000 cycles of practice output increased to 444 pieces per hour.



Incidentally, it requires approximately 50 per cent less time for a girl who has been through the training school to attain standard performance than for new girls going directly onto the production floor without the training.

During a two-year period more than 700 girls were trained in the manner described above.

#### EFFECT OF PRACTICE

If a person can perform a manual task at all, he can reduce the time per cycle for performing it with practice. The shape of the



FIG. 298. Punch-press operation—arrangement of work place.

learning curve will be affected by the nature of the work and by the traits, abilities, and attitude of the individual performing the task.

Figure 297 shows the learning curve for an operator assembling a mechanical pencil mechanism.<sup>5</sup> The operator on her first day of work averaged 200 assemblies per hour. After 11 days of practice she turned out 343 assemblies per hour, which was standard performance.

<sup>5</sup> L. F. Youde, *op. cit.*



Since the piece-work plan of wage payment was used in this plant, this operator earned a bonus for all work produced above the standard of 343 pieces per hour. Although the operator was producing 444 pieces per hour after 1500 hours of practice, it is apparent that the greatest

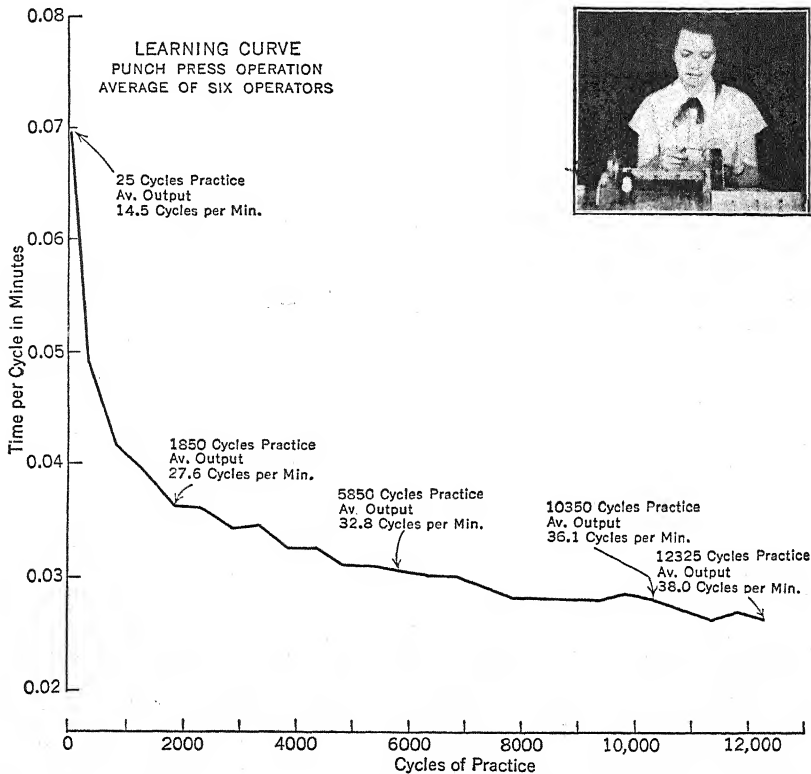


FIG. 299. Learning curve for punch-press operation. The average output without practice was 14.5 pieces per minute. This increased to 38 pieces per minute after 12,325 cycles of practice.

increase in production took place during the first few weeks of work on the job. At the end of the first week the operator had increased her output 25 per cent over that of the first day, and at the end of two weeks, she had increased it 68 per cent over that of the first day. After 38 weeks of practice, the total increase amounted to 122 per cent. Of this increase, over half took place during the first two weeks of practice.

Figure 299 shows the average learning curve for six operators performing a fairly complicated punch-press job involving the use of both



hands and one foot. The output increased 75 per cent after 1350 cycles of practice and doubled at the end of 3350 cycles of practice.

Figure 300 shows the learning curve for a very simple operation, that of filling a pinboard with 30 pins, using the two-handed method (see Fig. 66 on page 107). Here the output increased very rapidly because of the simplicity of this operation.

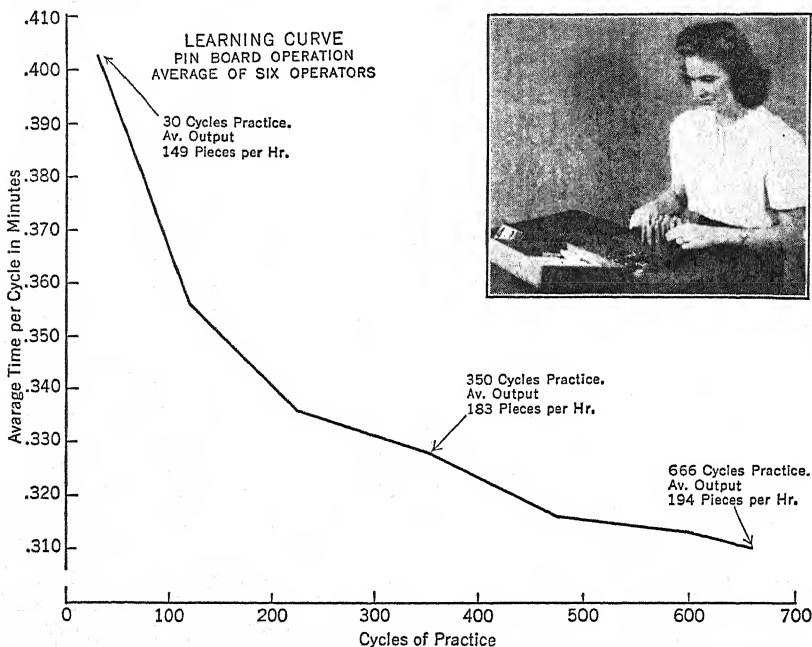


FIG. 300. Learning curve for pinboard operation. The average number of pieces per hour without practice was 149. This increased to 194 pieces per hour after 666 cycles of practice.

A number of studies<sup>6</sup> have been made of typical factory operations to determine the effect of practice on the fundamental hand motions. For example, on one job, while there was a reduction in time of 40 per cent after 3000 cycles of practice for the operation as a whole, the reduction in time for the transport loaded motion was 15 per cent whereas the reduction in time for the position was 55 per cent.

<sup>6</sup> See studies by Harold T. Amrine, "The Effect of Practice on Various Elements Used in Screwdriver Work," *The Journal of Applied Psychology*, Vol. 26, No. 2, pp. 197-209, April, 1942; and J. V. Balch, "A Study of Symmetrical and Asymmetrical Simultaneous Hand Motions in Three Planes," *Motion and Time Study Applications*, Section 14, pp. 70-72.



In another investigation <sup>7</sup> an attempt was made to determine through micromotion analysis the difference between the way the operator performed the job without experience and the way she performed it after she had become proficient on the job. Motion pictures were made of the operator as a beginner and then at intervals during the learning

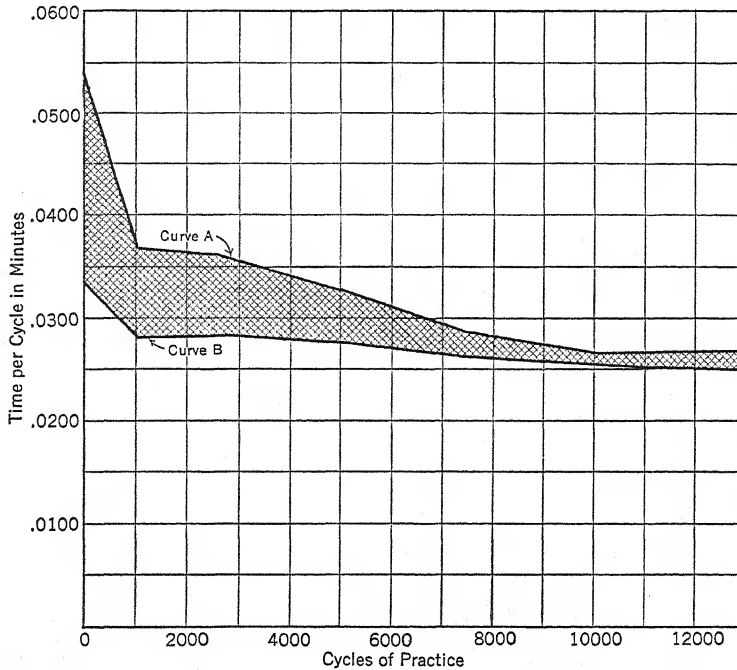


FIG. 301. Curves showing effects of fumbles and delays. Curve A is based on data including all fumbles and delays. Curve B is based on the same studies but excluding fumbles and delays.

period until she reached a high level of proficiency. Figure 301 shows the results of this study. The upper line A is the actual learning curve, whereas the lower line B is the learning curve with the fumbles, delays, and hesitations removed. This study shows that in this case two-thirds of the increase in output during the learning period can be attributed to the elimination of fumbles, delays, and hesitations on the part of the operator, and one-third perhaps to faster hand motions.

<sup>7</sup> Ralph M. Barnes, James S. Perkins, and J. M. Juran, "A Study of the Effect of Practice on the Elements of a Factory Operation," University of Iowa Studies in Engineering, *Bulletin* 22, p. 67, 1940.



The following is an analysis of the differences of the two learning curves:

The cycle time at the outset was 0.052 minute  
 The cycle time at the finish was 0.027 minute

The improvement was 0.025 minute

The improved performance can be traced to the following overlapping causes:

Reduction in fumbles and delays 0.017 minute  
 Faster performance 0.008 minute

Total 0.025 minute

There is evidence to show that the beginner does not use the same method that he will use after he becomes proficient in performing the

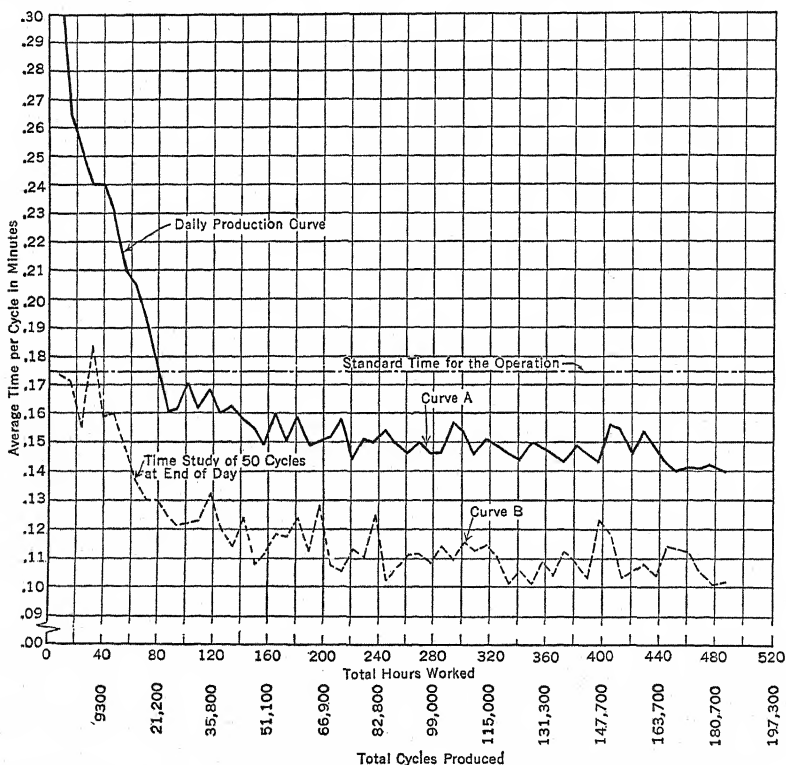


FIG. 302. Learning curves for mechanism assembly operation. Curve A is a record of the total daily output. Curve B is the actual time per piece as determined by a time study made of fifty cycles at the end of the day.



job. This difference in method is the biggest single factor affecting the cycle time for the job during the learning period.

**Lost Time.** The studies referred to above were made in the laboratory, and the conditions there are not always identical with those in the factory. Other studies seem to show that there is considerable difference between the average time per piece as determined by time study and the average time per piece when determined by dividing the number of minutes worked during the day by the number of pieces completed during the day. Figure 302 shows such information.<sup>8</sup> The upper curve A is a record of the total daily output, whereas the lower curve

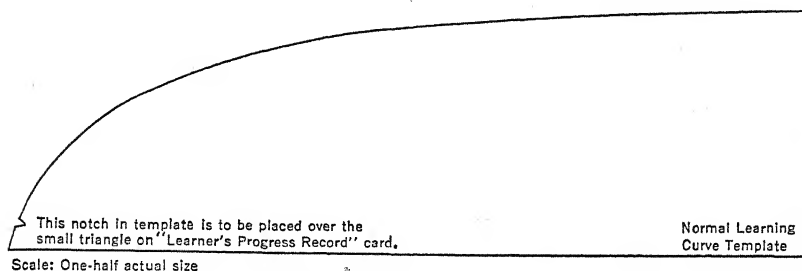


FIG. 303. Normal learning curve template (celluloid). The shape of this curve has been determined from studies of hundreds of different operations made by this company over a period of years.

B is the actual time per piece as determined by a time study made of fifty cycles at the end of the day. This shows that, as a beginner, the operator "loses more time" per day than she does after she has had some practice.

If the operator is given proper instruction, the learning period can be reduced, thus reducing unit labor cost to the employer and giving the operator greater satisfaction on his job. In time study work, emphasis is always placed on standardizing the method before setting a time standard for the job. The above discussion and the learning curves shown in this chapter would indicate that time standards should not be established from time studies made of inexperienced operators. Practical time study men know this only too well.

**Learner's Progress Record.** When a vacancy occurs, or when a new job is established, it is management's desire to select a person for the work who has the traits and qualities that will enable him to succeed on the job and to get personal satisfaction from it. It is also management's responsibility to train the worker so that he reaches

<sup>8</sup> L. F. Youde, *op. cit.*



standard performance in as short a period of time as possible. In order to have definite knowledge of the progress that a learner should make on a given job, some companies have made extensive studies of learning curves for various types of work and have prepared "normal learning curves" for their operations. The following procedure illustrates how such curves may be used.

**A Specific Case.** The purpose of the "Learner's Progress Record" is to compare the learner's progress with the average performance of

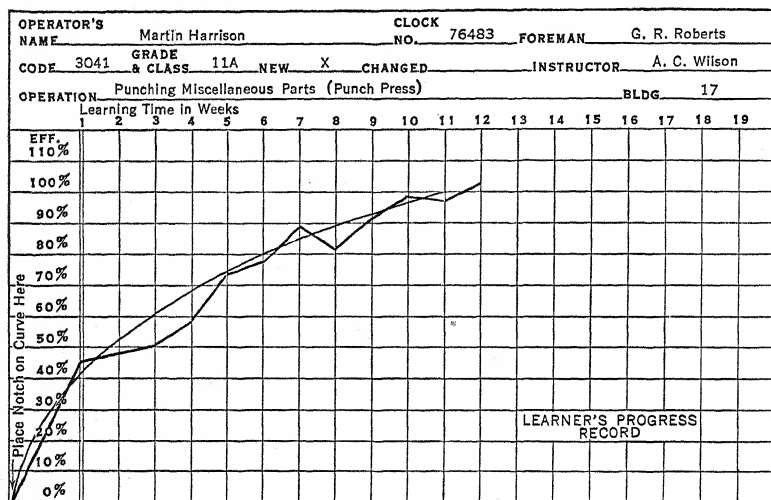


FIG. 304. Learner's Progress Record—front of card. Size of card 5×8 inches.

normal learners. This record serves also as a guide to the foreman and the instructor as to the necessary items to be included in the training of each learner. The "normal learning curve" is shown<sup>9</sup> in Fig. 303 and the "Learner's Progress Record" card is shown in Figs. 304 and 305. It should be emphasized that the normal learning curve developed by this company is only a rough indication of the expected output at intervals during the learning period. This curve is not sufficiently accurate for use as the basis for a wage incentive for learners.

The new employee or the employee who is assigned to a new job is turned over to an instructor, who incidentally is a skilled operator. This instructor, together with the foreman of the department, is re-

<sup>9</sup> The shape of the curve in Fig. 304 is different from the learning curves on the preceding pages because the vertical scale for Fig. 304 is "Efficiency in Per Cent" whereas that of the preceding curves is "Time per Cycle in Minutes."



sponsible for the learner's progress on the job. At the time the learner begins work, the "Learner's Progress Record" card (see Figs. 304 and 305) is filled out and the learning curve is constructed for the job in the following way. The normal curve, a template cut from a sheet of transparent celluloid, is used for all training periods. The curve is placed with the notch exactly on the black triangle in the lower left-hand corner of the card (see Fig. 304). The top of the template

C-4 OPERATOR'S RECORD				QUALITY: E-EXCELLENT G-GOOD F-FAIR P-POOR
STARTING DATE: December 3, 1947				ATTITUDE: Very good. Operator wants to learn the job.
RECORD WEEKLY				INSTRUCTOR'S CHECK
QUALITY RATING <input type="text"/>				TOOLS REQUIRED X
EFFICIENCY PERCENTAGE <input type="text"/>				INTRODUCTION X
F	F	G	G	QUALITY X
45	48	50	58	SAFETY AND HOUSEKEEPING X
G	G	G	E	COMMENTS:
74	79	89	83	COOPERATION X
E	E	E	E	FAIRNESS X
92	98	98	103	RATES OF PRODUCTION X
				ALLOWED PERSONAL TIME X
				At end of second week:
				Operator seems slow in learning job.
				At end of fourth week:
				Operator is still slow.
				He thinks he can handle the job.
				FOREMAN'S CHECK
				At end of sixth week:
				WAGE PAYMENT PLAN X
				Operator is progressing satisfactorily.
				POSSIBLE ADVANCEMENT X
				SAFETY X
				QUALITY X
				FOREMAN'S SIGNATURE
				INSTRUCTOR'S SIGNATURE
				CONTINUALLY STRESS SAFETY AND QUALITY X

FIG. 305. Learner's Progress Record—back of card.

intersects the 100 per cent horizontal line at the point of intersection of the vertical line designating the number of weeks' training required for that labor grade. A pencil line is drawn which follows the contour of the template, and this line represents the learning curve for the job in question. The card is retained by the foreman or instructor until the learner becomes proficient on the job (reaches 100 per cent efficiency) or changes jobs.

Each week the progress of the learner is recorded on the back of the card (see Fig. 305) in two ways. The efficiency percentage figure is computed and recorded in the appropriate box, and a letter designating the quality of the work done by the learner is inserted above and to the left of the efficiency figure. At the same time this information is recorded on the back of the card, a point representing the efficiency is plotted on the front of the card and a straight line is drawn connecting the zero point on the curve with the efficiency at the end of



JOB CLASSIFICATION			
CODE	2706	J.R.	DATE 8-24-46
OPERATION TYPE		SUPER.	DEPT. 3-7-9
INDEX NO.		PAYMENT	BLDG.
OCCUPATION:	Single or Multiple Spindle Drill Press Operator		WORK STATION OR GROUP NO.
<b>JOB IDENTIFICATION</b> Operate small size single or multiple spindle drill press to drive, tap, ream, countersink, and counterbore various parts and materials to specified location, depth, size, etc., with jigs and holding fixtures. Simple work on small and light parts of ordinary tolerances. Maintain set up by exchange of tools and simple adjustment. Check work.  TYPE OF OPERATOR DESIRED - Grammar school education. Girl of average height and size. Should be mechanically inclined.          LEARNING TIME - New operator 3 weeks.			

Fig. 306. Job Classification Card for small single or multiple spindle drill.

JOB CLASSIFICATION			
CODE	L2746	J.R.	DATE 3-31-47
OPERATION TYPE		SUPER.	DEPT. 4
INDEX NO.		PAYMENT	BLDG. 24W
OCCUPATION:	Engine Lathe Operator		WORK STATION OR GROUP NO.
<b>JOB IDENTIFICATION</b> DESCRIPTION OF WORK - Get job assignment and secure proper materials and necessary tools for the job. Place work in machine either by chucking or placing between centers. Set up cross slide tools to make necessary cuts. Determine the depth and number of cuts to be made in machining work to drawing and specifications. Machine work as outlined above. Remove work from machine and identify if necessary.  EQUIPMENT USED - 24" Lodge & Shipley, 12' x 24" Prentice, 9' x 18" Chard, and 10' x 25" LaBlond engine lathes, machinist tools, micrometers, callipers, pin gauges, crane.  TYPE OF OPERATOR DESIRED - High school graduate or equivalent with previous lathe experience. Must be able to work to close tolerances and read blueprints.  TYPE OF WORK PERFORMED - Bearings, thrust collars, gear and pinion, etc.   LEARNING TIME - New operator 9 weeks; semi-experienced operator 6 weeks.			

Fig. 307. Job Classification Card for engine lathe.



the first week. In a similar manner the efficiency is recorded and plotted each week, and the quality of the work is indicated on the back of the card. The learning curve is shown to the operator when he first begins work on the job and its meaning and purpose are discussed with him in detail. Then, each week after the learner's performance has been posted on the card, the instructor or the foreman goes over the operator's accomplishment with him. They discuss each of the items listed on the back of the card, such as quality, safety, and good housekeeping. Each item is checked after it has been thoroughly explained to the learner.

The instructor also records the attitude of the learner toward the job. Notes are also recorded concerning the learner's progress and any irregularities that may have occurred during the period.

After the operator reaches standard performance (100 per cent efficiency), the Learner's Progress Record card is sent to the supervisor of training, where it is permanently filed with other records of the employee.

The procedure described above has proved to be a very effective method of keeping the employee, as well as the foreman, informed each week as to the progress being made. In those cases where an operator proves to be unsuited to the work and his output consistently falls below the expected production, it is possible to transfer the person to other work without excessive loss of time.

**Job Classification Card.** The "Job Classification Card" contains a rather complete description of the job. (See Figs. 306 and 307.) It shows the labor grade and the learning time for a new operator as well as for a semi-experienced operator. A new operator is defined as one who has had no experience on the particular type of work, and a semi-experienced operator is one who has had some experience on the particular job or machine.

Figure 306 is a job classification for a small-size single or multiple-spindle drill. The learning time for a new operator is three weeks. Figure 307 is a job classification for an engine lathe. The learning time for a new operator is nine weeks, and for a semi-experienced operator, six weeks.



# APPENDIX

## WORK METHODS TRAINING

A methods improvement program like any other important activity in an organi successful. In fact, every executive, manager, and supervisor must be acquainted and approaches used in developing better work methods. For this reason it is ment. The preview outline shown below requires two to three hours to present, A fuller presentation is to be preferred if time is available.

Subject	Demonstration
<i>Introduction</i>	
1. Scope of Industrial Engineering (place of Methods Improvement Program).....	
2. Outline of Methods Improvement Program—purposes of Program.....	
3. Introduction:	
a. Good work methods enable a person to accomplish more with less effort	
(1) On manual operations—pin board demonstration.....	x
(2) On machine-paced operations—toaster demonstration.....	x
<i>Methods Improvement Program—Tools and Techniques</i>	
4. Developing a better method.....	
<i>Process Analysis</i>	
5. Process analysis—process charts, flow diagrams, and gang process charts	
a. Purposes of process analysis.....	
b. Process charts and flow diagrams—process chart symbols.....	
c. Process chart and flow diagram—water garden.....	
d. Process chart and flow diagram—re-coating buffing wheels:	
(1) Motion picture—old method—re-coating buffing wheels with emery.....	
(2) Chart—flow diagram—old method.....	
(3) Chart—process chart—old method.....	
(4) Chart—what, why, who, where, when, how.....	
(5) Chart—analyze the work—develop a better method.....	
(6) Discussion of suggestions for improving job.....	
(7) Motion picture—improved method—re-coating buffing wheels with emery.....	
(8) Chart—flow diagram—improved method.....	
(9) Chart—process chart—improved method.....	
(10) Results of installation of improved method.....	
e. Analysis of work on small dairy farm—motion picture of feeding silage.....	
(1) Chart—flow diagram—old method—feeding silage.....	
(2) Chart—flow diagram—improved method—feeding silage.....	



# A

## PROGRAM—A PREVIEW

zation must be understood and fully supported by top management if it is to be with the purposes and objectives of the program and must understand the principles essential that a preview of or an introduction to the program be given to top management and this is the minimum time that should be allowed for this phase of the program.

Slides or Charts	Motion Pictures	References
Scope of Industrial Engineering		MTS, <sup>1</sup> p. 4; also any textbook <sup>2</sup> on "Industrial Engineering and Management"
MTS, Fig. 1		MTS, Preface and Chap. 1 WMM, Preface and Chap. 1
		MTS, Figs. 65, 66, 67, and 313; WMM, pp. 63-65, 89-90, 130
		MTS, Fig. 310; WMM, pp. 48-49, 127
		MTS, Chap. 4; WMM, Chap. 2
MTS, Fig. 5, or WMM, Fig. 14	U-2342 <sup>3</sup> Flow Process Charts and How to Make Them	MTS, p. 28; WMM, pp. 19-20
MTS, Figs. 7 and 8, or WMM, Figs. 15 and 16	U-1965 Better Work Methods	MTS, pp. 34-36; WMM, pp. 23-30
MTS, Fig. 12, or WMM, Fig. 22		MTS, p. 23; WMM, p. 10
MTS, Fig. 13, or WMM, Fig. 23		MTS, p. 23; WMM, p. 10
MTS, p. 23, or WMM, p. 10		
MTS, p. 23, or WMM, p. 10		
MTS, Fig. 15, or WMM, Fig. 25	U-1693 Making Minutes Count (feeding silage)	MTS, pp. 35-37
MTS, Fig. 16, or WMM, Fig. 26		MTS, p. 39; WMTM, pp. 132-149
MTS, Fig. 18, or WMTM, p. 140		
MTS, Fig. 19, or WMTM, p. 142		

<sup>1</sup> See references on page 509.

<sup>2</sup> See "Principles of Industrial Organization," 6th ed., by Kimball and Kimball, McGraw-Hill Book Co., N. Y., pp. 152-153, 1947.

<sup>3</sup> See references on page 509.



## WORK METHODS TRAINING

Subject	Demonstration
<i>Equipment Utilization</i>	
6. Equipment utilization—activity charts, and man and machine charts	
a. Introduction—activity charts	
b. Activity chart—sandblast castings	
(1) Layout of work place—old method	
(2) Activity chart—old method	
(3) Layout of work place—improved method	
(4) Activity chart—improved method	
c. Simple type of man and machine chart—drill $\frac{1}{4}$ -inch hole in cast iron plate	
d. Man and machine chart—slitting coated fabric	
(1) Slitting machine	
(2) Man and machine chart—old method	
(3) Pedestal for holding rolls of fabric	
(4) Man and machine chart—improved method	
e. Man and machine chart—applications in the oil fields	
(1) Pulling rods—oil well servicing—old method and improved method	
f. Toaster problem—man and machine chart—old method	
Toaster problem—man and machine chart—improved method	
<i>Operation Analysis</i>	
7. Operation analysis—job breakdown, left- and right-hand charts, and operation charts	
a. Operation study—get and put	
b. Left- and right-hand chart—bolt and washer assembly	
c. Use of two symbols—operation chart of signing letter	
<i>Micromotion Study</i>	
8. Micromotion study—film analysis, simo charts	
a. Introduction	
b. Definition of fundamental hand motions	
(1) Putting cap on mechanical pencil—Define motions	x
(2) Using screwdriver—Define motions	x
(3) Placing pins in pin board—Define motions	x
(4) Assembling washers onto bolt	x
<i>Principles of Motion Economy</i>	
9. Introduction	
a. Twenty-two principles of motion economy—Place emphasis on those principles which seem most applicable in your plant	
<i>Putting Improved Method into Effect</i>	
10. Putting improved method into effect	
a. Get ideas from all those interested in the job. Ask for suggestions while job is being studied	
b. Try out the proposed method	
c. Get approval—Show how proposed method will make work easier, safer, and better—How it will reduce labor costs, save material, etc. Use charts to present facts if necessary	
d. Estimate cost and time involved in putting improved method into effect	
e. Give credit where due	
f. Install the new method—Make it work. Follow up to see that operators do not revert to the old method	



# A (Continued)

## PROGRAM—A PREVIEW

Slides or Charts	Motion Pictures	References
MTS, Fig. 38, or WMM, Fig. 31 MTS, Fig. 39, or WMM, Fig. 32 MTS, Fig. 40, or WMM, Fig. 33 MTS, Fig. 41, or WMM, Fig. 34 MTS, Fig. 42, or WMM, Fig. 35		MTS, pp. 60-61; WMM, pp. 34-38
MTS, Fig. 44, or WMM, Fig. 37 MTS, Fig. 46, or WMM, Fig. 39 MTS, Fig. 45, or WMM, Fig. 38 MTS, Fig. 47, or WMM, Fig. 40		MTS, pp. 66-72; WMM, pp. 37-43
WMTM, p. 87 WMM, Fig. 47 WMM, Fig. 108	U-1535 Job Design—Pulling Rods	WMTM, pp. 81-90
MTS, Fig. 51, or WMM, Fig. 49 MTS, Fig. 50, or WMM, Fig. 48		MTS, pp. 74-90; WMM, pp. 15-18 and 50-57
MTS, Fig. 62 MTS, Fig. 64, or WMM, Fig. 53		MTS, pp. 91-94; WMM, pp. 58-71 MTS, pp. 95-109; WMM, pp. 58-69
MTS, Fig. 65, or WMM, pp. 66-67 MTS, Fig. 78, or WMM, Fig. 57, or MSA, p. 186 and insert	U-979 Motion Study Applications B100 Micromotion Analysis Film Bolt and Washer Assembly—old method	MTS, pp. 104-109 MTS, pp. 194-197
MTS, Fig. 144, or WMM, Fig. 73A MTS, Fig. 145, or WMM, Fig. 73B	U-919 Motion Study Principles U-1442 Motion Study in Action U-1993 Machine Tools and Motions	MTS, pp. 191-312; WMM, pp. 72-122 WMTM, pp. 91-184; MSA, pp. 98-137
		MTS, pp. 460-469; WMM, p. 123 MTS, pp. 468-469; WMM, p. 123 MTS, pp. 463-465
		MTS, Fig. 225
		MTS, pp. 482-496

*References:* MTS = "Motion and Time Study," Third Edition.

WMM = "Work Methods Manual," First Edition.

MSA = "Motion and Time Study Applications," First Edition, 1948 Printing.

WMTM = "Work Methods Training Manual," Second Edition.

*Note:* All the above books are by Ralph M. Barnes. First three books are published by John Wiley and Sons, New York. Last book is published by Wm. C. Brown Co., Dubuque, Iowa.

Motion pictures are 16-mm. sound or silent and are loaned within the United States by the Bureau of Visual Instruction, University of Iowa, Iowa City, Iowa. For a complete list of Motion and Time Study Loan Films, see WMTM, pp. 17-30.



# APPENDIX

## WORK METHODS TRAINING

The work methods training program outlined below may profitably be presented signers, mechanical engineers, group leaders, and key operators. Thirty to forty

Subject	Demonstration
<i>Introduction to Course</i>	
1. Scope of Industrial Engineering (place of Methods Improvement Program) .....	
2. Outline of course content—purposes of Methods Improvement Program .....	
<i>Methods Improvement Program—Tools and Techniques</i>	
3. Developing a better method. ....	
<i>Process Analysis</i>	
4. Process analysis—process charts, flow diagrams, and gang process charts	
a. Purposes of process analysis. ....	
b. Process charts and flow diagrams—process chart symbols. ....	
c. Process chart and flow diagram—water garden. ....	
d. Process chart and flow diagram—re-coating buffing wheels:	
(1) Motion picture—old method—re-coating buffing wheels with emery. ....	
(2) Chart—flow diagram—old method. ....	
(3) Chart—process chart—old method. ....	
(4) Chart—what, why, who, where, when, how. ....	
(5) Chart—analyze the work—develop a better method. ....	
(6) Discussion of suggestions for improving job	
(7) Motion picture—improved method—re-coating buffing wheels with emery. ....	
(8) Chart—flow diagram—improved method. ....	
(9) Chart—process chart—improved method. ....	
(10) Results of installation of improved method. ....	
e. Make process chart and flow diagram of some simple activity in your plant or office:	
(1) Get information, make process chart and flow diagram of present method. ....	x
(2) Solicit suggestions from group for a better method	
(3) Make process chart and flow diagram of proposed method. ....	x
f. Analysis of work on small dairy farm. ....	
(1) Chart—feeding silage—flow diagram of old method. ....	
(2) Chart—feeding silage—flow diagram of improved method. ....	
g. Make process chart and flow diagram of some activity in your plant or office:	
(1) Get information by an “on-the-job analysis” of the activity. Make process chart and flow diagram of present method	
(2) Solicit suggestions from group for a better method	
(3) Make process chart and flow diagram of proposed method	
h. Ask each person to make a study of some activity in his department. Have him make process charts and flow diagrams of present and proposed methods. Ask him to present his proposed method to the group	
i. Gang process chart. ....	
(1) Make gang process chart of some activity in your plant or office	
j. Process analysis and equipment design. ....	



## B

### PROGRAM—THE MAIN PROGRAM

to industrial engineers, supervisors, foremen, process engineers, tool and jig de-  
hours are required to complete this program.

Slides or Charts	Motion Pictures	References
Scope of Industrial Engineering	.....	MTS, <sup>1</sup> p. 4; also any textbook <sup>2</sup> on "Industrial Engineering and Man- agement"
MTS, Fig. 1	.....	MTS, Preface, and Chap. 1; WMM, Preface, and Chap. 1
.....	.....	MTS, Chap. 4; WMM, Chap. 2
.....	.....	MTS, pp. 28-31; WMM, pp. 19-20
MTS, Fig. 5, or WMM, Fig. 14	U-2342 <sup>3</sup> Flow Process Charts and How to Use Them	
MTS, Figs. 7 and 8, or WMM, Figs. 15 and 16	.....	
.....	U-1965 Better Work Methods	MTS, pp. 34-36; WMM, pp. 23-30
MTS, Fig. 12, or WMM, Fig. 22	.....	MTS, p. 23; WMM, p. 10
MTS, Fig. 13, or WMM, Fig. 23	.....	MTS, p. 23; WMM, p. 10
MTS, p. 23, or WMM, p. 10	.....	
MTS, p. 23, or WMM, p. 10	U-1965 Better Work Methods	
MTS, Fig. 15, or WMM, Fig. 25	.....	MTS, pp. 35-37
MTS, Fig. 16, or WMM, Fig. 26	.....	
.....	U-1693 Making Minutes Count	MTS, p. 39; WMTM, pp. 132-149
MTS, Fig. 18, or WMTM, p. 140	.....	
MTS, Fig. 19, or WMTM, p. 142	.....	
.....	.....	MTS, pp. 50-53; WMTM, p. 290
MTS, Figs. 32 and 33	.....	
.....	U-797 Extractor Operations in a Commer- cial Laundry	MTS, pp. 56-57; 72-73

<sup>1</sup> See references on page 515.

<sup>2</sup> See "Principles of Industrial Organization," 6th ed., by Kimball and Kimball, McGraw-Hill Book Co., N. Y., pp. 152-153, 1947.

<sup>3</sup> See references on p. 515.



# APPENDIX

## WORK METHODS TRAINING

Subject	Dem- onstra- tion
<i>Equipment Utilization</i>	
5. Equipment utilization—activity charts, and man and machine charts a. Introduction—activity charts. .... b. Activity chart—sandblasting castings (1) Layout of work place—old method. .... (2) Activity chart—old method. .... (3) Layout of work place—improved method. .... (4) Activity chart—improved method. .... c. Man and machine chart—drill ¼-inch hole in casting (put chart on blackboard) ..... x d. Man and machine chart—slitting coated fabric. .... (1) Slitting machine. .... (2) Man and machine chart—old method. .... (3) Pedestal for holding rolls of fabric. .... (4) Man and machine chart—improved method. .... e. Man and machine chart—applications in the oil fields. .... (1) Pulling rods—oil well servicing. .... (2) Pulling tubing—oil well servicing. .... (3) Taking up pipe—oil well servicing. .... f. Toaster problem—assign problem to be worked outside—or solve in conference room. .... x g. Get information in plant or office and make man and machine chart h. Comparison of gang process chart and man and machine chart. Show advantages and disadvantages of each type of chart	
<i>Operation Analysis</i>	
6. Operation analysis—job breakdown, left- and right-hand charts, and operation charts a. Introduction. .... b. Left- and right-hand chart—bolt and washer assembly. .... c. Use of two symbols—signing letter (put chart on blackboard) ..... x d. Clean-up work—mopping floor—old method and improved method. ....	
<i>Micromotion Study</i>	
7. Micromotion study—film analysis, simo charts a. Introduction. .... b. Definition of fundamental hand motions. .... (1) Putting cap on mechanical pencil. .... x (2) Using pen in signing letter. .... x (3) Using screwdriver. .... x (4) Opening bottle. .... x (5) Filling pin board. .... x c. Film analysis. .... (1) Bolt and washer assembly—old method. .... x (2) Bolt and washer assembly—improved method. .... x (3) Make film analysis of simple operations in your own plant or office. .... d. Development of a better method (1) Study "The Use of Fundamental Hand Motions" .....	



B (Continued)

PROGRAM—THE MAIN PROGRAM

Slides or Charts	Motion Pictures	References
		MTS, pp. 60-61; WMM, pp. 34-38
MTS, Fig. 38, or WMM, Fig. 31 MTS, Fig. 39, or WMM, Fig. 32 MTS, Fig. 40, or WMM, Fig. 33 MTS, Fig. 41, or WMM, Fig. 34		
MTS, Fig. 44, or WMM, Fig. 37 MTS, Fig. 46, or WMM, Fig. 39 MTS, Fig. 45, or WMM, Fig. 38 MTS, Fig. 47, or WMM, Fig. 40		MTS, pp. 66-72; WMM, pp. 37-43
WMTM, p. 87 WMTM, p. 89	} U-1535 Job Design as Applied to Petroleum Production	WMTM, pp. 81-90
MTS, Fig. 310, or WMM, Fig. 46		MTS, p. 524; WMM, pp. 48, 127
MTS, Fig. 51, or WMM, Fig. 49 MTS, Fig. 50, or WMM, Fig. 48	U-674 Motion Study Applied to Factory Clean-Up	MTS, pp. 74-90; WMM, pp. 15-18 and 50-57  MTS, pp. 85-90
MTS, Fig. 62 MTS, Fig. 64, or WMM, Fig. 53 MTS, Fig. 63, or WMM, pp. 59-61	U-979 Motion Study Applications	MTS, pp. 91-94; WMM, pp. 58-71 MTS, pp. 97-109; WMM, pp. 58-69
MTS, Fig. 65, or WMM, pp. 66-67	U-979 Motion Study Applications	WMM, Fig. 110
MTS, Fig. 78, or WMM, Fig. 57, or MSA, p. 186 and insert MSA, p. 186 and insert	B-100 Micromotion Analysis Film (1)  B-100 Micromotion Analysis Film (2) Note: Make analysis from your own film	MTS, pp. 128-148
	U-687 Investigation of Some Hand Motions U-669 Spray-Painting Refrigerator Units U-1001 Demonstrations in Reaction Time	MTS, pp. 149-179; MSA, pp. 40-96



# APPENDIX

## WORK METHODS TRAINING

Subject	Dem- onstra- tion
<i>Principles of Motion Economy</i>	
8. Introduction.....	
a. Twenty-two principles of motion economy—place emphasis on those principles which seem most applicable in your plant .....	
b. Have each person apply the principles of motion economy to a specific case from his department. ....	
<i>Putting Improved Method into Effect</i>	
9. Introduction.....	
a. Get opinions and ideas from all those interested in the job. Ask for suggestions while job is being studied .....	
b. Try out the proposed method.....	
c. Get approval—show how proposed method will make work easier, safer, and better—how it will reduce labor costs, save material, etc. Use charts to present facts if necessary .....	
d. Estimate cost and time involved in putting improved method into effect.....	
e. Give credit where due .....	
f. Install the new method—make it work. Follow up to see that operators do not revert to the old method .....	
<i>Wages, Profits, Employment, and Technological Change</i>	
10. Introduction.....	
a. How to raise wages, machinery creates employment, case of the continuous steel mill .....	
b. Eastman Kodak illustration.....	
c. Present information from your own organization similar to that referred to above .....	



# B (Continued)

## PROGRAM—THE MAIN PROGRAM

Slides or Charts	Motion Pictures	References
MTS, Fig. 144, or WMM, Fig. 73A MTS, Fig. 145, or WMM, Fig. 73B <i>Note:</i> Use other illustrations to fit your own situation.	U-919 Motion Study Principles U-1442 Motion Study in Action U-1993 Machine Tools and Motions U-1965 Cresting Letters on Glasses U-686 Soldering and Small Assembly Operations U-796 Study of Pedal Design	MTS, pp. 191-312; WMM, pp. 72-122; WMTM, pp. 91-184; MSA, pp. 98-137
		MTS, pp. 463-465
		MTS, pp. 460-469; WMM, p. 123
		MTS, pp. 468-469; WMM, p. 123
		MTS, pp. 463-465
		MTS, Fig. 225
		MTS, pp. 482-496
		MTS, pp. 322-332; WMM, pp. 5-8; MSA, pp. 1-16
WMM, Fig. 2; WMM, Fig. 3; WMM, Fig. 4; WMM, Fig. 5; WMM, Fig. 6		

*References:* MTS = "Motion and Time Study," Third Edition.

WMM = "Work Methods Manual," First Edition.

MSA = "Motion and Time Study Applications," First Edition, 1948 Printing.

WMTM = "Work Methods Training Manual," Second Edition.

*Note:* All the above books are by Ralph M. Barnes. First three books are published by John Wiley and Sons, New York. Last book is published by Wm. C. Brown Co., Dubuque, Iowa.

Motion pictures are 16-mm. sound or silent and are loaned within the United States by the Bureau of Visual Instruction, University of Iowa, Iowa City, Iowa. For a complete list of Motion and Time Study Loan Films, see WMTM, pp. 17-30.



## APPENDIX C

### TIME STUDY MANUAL

#### I. Time Study Department Responsibility

- A. The determination and administration of all factory wages.
  - 1. Hourly day-work rates established by job evaluation.
  - 2. Standard times and unit piece-work rates as established by time study.
  - 3. Determination and maintenance of the wage-payment system.
- B. The coordination of the development of all factory production methods.
- C. The preparation and maintenance of plant layout.
- D. The determination of the proper kinds and quantity of new and replacement equipment.

#### II. Definition of Time Study

Time Study is the analysis of a job for the purpose of determining the time that it should take a qualified person, working at a normal pace, to do the job, using a definite and prescribed method. This time is called the *standard time* for the operation.

#### III. Purposes of Time Study

- A. As a basis for determining time standards and establishing piece-work rates.
- B. As a basis for establishing a "Standard Day's Work" for jobs paid on a day-work basis.
- C. As an aid in improving methods.
- D. For production planning and control purposes.
- E. For cost-control purposes.

#### IV. Requests for Time Study

- A. *Request for time study by foreman when a new job is put into production.*

The foreman will request the time study department in writing, on Time Study Form TS101 (see Fig. 308), provided by the time study department, to make a study of a new operation when he considers the job ready. Before requesting a time study the foreman should make certain that those conditions listed below have been met.

##### PREPARATION TO BE MADE BY FOREMAN BEFORE STUDY IS REQUESTED

- 1. A satisfactory method of performing the operation must be developed. This method may not be the very best obtainable, but it should take into consideration such factors as sequence and economy of motions, distance materials have to be moved, including arrangements for delivery and removal of supplies by service personnel, and work-place layout.



2. The machinery and equipment must be running at the correct speed and be in good working order. Tools, dies, fixtures, or any auxiliary equipment must be functioning properly and must be adapted to the job.
3. Materials must meet the specifications set by the pattern department and laboratory. A study will not be made while abnormal stock conditions exist. Re-studies will not be made if the quality of materials

REQUEST FOR PIECE RATE	
To: Time Study Department	Department _____
_____ has been set up in my department. (operation name)	
The following points have been checked:	
Number of operators involved _____ (    )	Operator is qualified and experienced on
Machine is working properly _____ (    )	this job _____ (    )
Materials are to specification _____ (    )	Operator has been notified that operation
Best work area is utilized _____ (    )	is to be timed _____ (    )
	Necessary tools and equipment are available (    )
I believe this job is ready for time study.	
Date _____	Signed _____ Foreman
NOTE: <u>The information on the bottom of sheet to be filled in by Time Study Department.</u>	
Date received _____	Date checked _____
Date studies taken _____	Observer _____
Date rate effective _____	
Other disposition _____	
Signed by _____	
TS 101	

FIG. 308. Request for piece rate—Form TS 101.

during the rate trial period fluctuate beyond normal specification limits.

4. The operator must be trained to perform the operation using the method, machine, tools, and equipment that have been specified and should have gained sufficient skill through experience on the job to be studied, to display efficient performance. It is not advisable to make a time study of an inexperienced operator. In most cases it will be found that an inexperienced operator has so many fumbles, delays, and hesitations that it is practically impossible to segregate the true element time from the fumbles and delays.
5. The foreman must discuss the job with the operator and point out the reason why a time study is being requested.



*B. Request for time study or production study by foreman when a time standard and piece-work rate is already in effect.* The foreman will request in writing, on the standard form, that the time study department make a re-study of the operation.

1. A time study will be made if there has been a change in method, work-place layout, materials, or tools and equipment used on the operation.
2. A production study will be made if the operator who was performing the job at the time the time study was made, or a different operator, is unable to reach the day-work standard of performance after a reasonable period of time while using the prescribed method and materials and exhibiting normal effort.

*C. Request for time study or production study by other persons.* In some cases persons other than the foremen, such as the factory manager, chief chemist, pattern and design, cost, purchasing, or sales departments, may, for the purpose of securing information pertaining to their particular function in management, request that a time study be made. These requests will be made on a Form TS102, which is obtainable in the time study department.<sup>1</sup> In such cases the time study man will contact the foreman explaining the reason for making the special time study.

#### V. Time Study Procedure

*A. Contact the foreman.* The time study man will contact the foreman upon entering the department. The foreman will show the time study observer the location of the job and will check the operation to see that the proper method is being used.

*B. Make contact with the operator to be timed.* In no case should a time study man start making a time study without the operator's knowledge. If there are several operators doing the same job the person who is giving the nearest to a normal performance should be studied. In fact, two or more operators might be studied if this seems advisable. Under no circumstances should rates be set on the basis of time studies made of inexperienced operators or operators who are unwilling to cooperate.

*C. Check operation for method.* When a new item is put into production or when a new piece of equipment is installed, a number of people may be involved in the development of a method. The time study department should be consulted in such matters. It is the time study department's responsibility to check the method for possible improvement before setting a time standard for the job. The time study man may only suggest possible changes, he will not inaugurate them unless requested to do so. Before making a time study of a job the time study man should have the foreman approve the method in use. This will include an examination of the elements of the job to be timed and approval of them as to their completeness.

*D. Obtain all necessary information.* The time study man should obtain and record on the time study observation sheet, Form TS103 (see Fig. 252), all the necessary information about the job, machine, and materials that he

<sup>1</sup> This form not shown here.



needs to fully complete his study. A drawing or layout of the work place should be made showing the location of the operator, materials, tools, etc. Whenever necessary, a process chart showing the location of the particular operation in the process should be made. A sketch of the part should be included with the time study whenever it seems advisable.

*E. Divide the operation into elements.* The operation should be divided into elements as short in duration as can be accurately timed. The beginning and ending points of these elements usually are easily determined because they come at natural break points in the operation. It is important that each element be carefully defined so that the starting and stopping point will be exactly the same in each cycle timed. Handling time should be separated from machine time, and constant elements should be separated from variable elements wherever possible.

*F. Record the time.* The purpose of timing the operation is to obtain the representative time taken for each element of work in the operation. It is the policy therefore to carefully time each and every part of the operation. If, for example, a "book leaf" must be turned once every ten pairs of parts cemented, such information should be recorded on the time study sheet, and a sufficient number of cycles including this element should be timed in order that the representative time for this element can be obtained.

When foreign elements occur they should be timed and recorded on the time study sheet. These elements may or may not be included in the time standard, depending on their nature. It is necessary on the time study observation sheet to account for all the time consumed by the operator while the time study is being made. The foreign elements must be very carefully reviewed to determine if they should be incorporated in the time standard, or if they are unnecessary delays caused by the operator. Personal time and time for rest and some unavoidable delay are incorporated in time study allowances and should not be included as elements in the time study as this would be a duplication.

The time study man should record the time of day the study was started and the time it was finished, thus obtaining the elapsed time. The total number of units finished during the study should also be recorded.

*G. Rate operator's performance.* We all know that there is a difference in the effort or speed at which different people naturally work. For example, a few people usually walk at a slow pace and a few people at a very fast pace, while most walk at a pace somewhere between these two extremes. So in the factory some people work at a slow pace while others work at an excellent pace. The normal day-work pace is given an index number of 100 points in making a time study. A qualified operator who is trained to work correctly with the specified materials, tools, and equipment, and who is working at the pace expected from an individual being paid by the hour, and therefore without incentive, is said to be working at a 100-point pace. For the purposes of comparison it is expected that a few especially fast operators might reach a pace of 130 to 150 points when on incentive. The operator's performance or pace is rated when the time study is made and the rating index is applied to the time study data in order to determine the standard time for the job.



## VI. Computation of the Time Standard and Piece-Work Rate

A. *Compute the normal time.* The representative time for each element should be determined and recorded in its proper place on the observation sheet. This representative time should be multiplied by the rating factor to obtain the normal time for the element.

B. *Prepare the computation sheet Form TS104 (Fig. 254).*

1. Transfer the element name and its normal time from the time study observation sheet to the computation sheet. The elements should be listed in the sequence of performance.
2. At this point, other studies of similar operations contained in the files and any standard data that are available should be reviewed to supplement the information contained in the new time study.
3. In the fourth column, headed "Units per Element," is placed the number of units that are completed in the element. The unit referred to is the unit of physical count, i.e., one yard, one pair, one batch, etc. *An example:* 8 pairs (16 pieces) of heel pieces are placed on a "leaf of a book" and the next leaf is turned. In this instance "8 pairs" is recorded in column 4.
4. In the fifth column, headed "Occurrence of Element per (.....)," is to be recorded the number of times this element occurs per 100 pairs or per other unit that may be used as a base.
5. Multiply the normal time per element by the occurrence of the element per 100 pairs (or per other unit that is used as a base) and record the result in column 6 on the computation sheet.
6. Obtain the total normal time for all elements by adding together the normal times of each element.
7. Add allowances for fatigue, personal needs, and delay to the total normal time of all elements to obtain the total standard time for the operation.
8. Divide the total standard time for the operations into 60 minutes and multiply by 100 to obtain the day-work hourly production. This then is the number of pieces or amount of work that has been established by time study to be the hourly task that an operator should complete when working at a normal pace, that is, at a day-work pace and without incentive.

C. *Compute the piece-work rate.* To compute the piece-work rate the basic hourly wage or day-work rate which has been assigned to the job is divided by the day-work hourly production. Piece-work rates are usually expressed in dollars and cents per unit or 100 units.

## VII. Preparation for Rate Installation

- A. Discuss the time standard with the foreman. At this point the foreman is contacted and all phases of the time study are discussed with him. Sufficient discussion time will be taken so that the foreman will be completely familiar with all phases of the time study and will therefore be in a position to describe it to the operator in a constructive manner, and he will be able to answer any questions that the operator may have.



*B. Determine the method of application of the piece-work rate.*

1. Determine the exact manner in which production and time are to be measured and recorded. Design any forms necessary to report the amount of work finished per day.
2. Whenever necessary prepare a statement of the payroll procedure to be followed in computing workers' earnings.

ELEMENTS OF JOB	
DEPARTMENT	Shoe Room
FOREMAN	W.M. Wilson
OPERATION Assemble and Cement Heel Plugs on Swing Boot Insoles	
PIECE WORK JOB NO. 16-15	
DAY WORK JOB NO. 16-16 DAY WORK HOURLY PROD. 237 Pr.	
NO.	ELEMENTS OF JOB
1	Get Supply of Heel Plugs
2	Get Supply of Insoles
3	Get, Loosen, and Lay Out Insoles in 15 Piles
4	Get, Pick, and Spot Heel Plugs on Insoles
5	Get Brush of Cement, Cement, and Aside Brush
6	Stack Completed Work
7	Mark Size on Stack
8	Aside Completed Work
9	Get Cement Supply
10	Empty and Clean Cement Pan
11	Clean Up Work Place and Cover Work
12	Record Production
13	
14	
15	
16	
17	
18	
19	
20	
Note: Whenever any one of the of the original conditions or the above elements are changed or eliminated, or when the worked place lay out is changed in any manner, the job must be checked by the Time Study Department.	
TS 105	

Fig. 309. Elements of job—Form TS 105.

**VIII. Putting Piece-Work Rate into Effect**

- A. Several copies of the piece-work rate sheets will be made. Two copies will contain signatures of approval by the superintendent and the head of the



time study department. All copies will contain the effective date, basic hourly wage, day-work hourly production, piece-work unit rate as well as the operation name, number, and the department.

- B. A copy of the standard element sheet, TS105 (see Fig. 309), and a copy of the piece-work rate sheet, TS106 (see Fig. 255), will be given to the foreman. Information about each new piece-work rate installation will be supplied by the time study department to the payroll department and to the interested persons in the other departments.

#### **IX. Follow-up of the Piece-Work Rate Application**

Soon after an operator begins working on incentive a check will be made of his production by the foreman or by the time study man separately or together. The foreman will in every case make a production check once each hour during the trial period. These production records are to be turned in on Form TS107<sup>2</sup> to the time study department at the end of each day for analysis. At least once during the first ten-day period following the installation of the piece-work rate, a time study man and the foreman will jointly compare the operation with the standard element sheet. If further checks are required, production studies will be made by the time study department. Whenever any methods, materials, tools, or related equipment are changed in any way, the time study department must be notified so that they may have an opportunity to determine if a change in rate is necessary.

This manual was prepared by Earl L. Frantz, with the assistance of James A. Kenyon and Robert J. Parden.

<sup>2</sup> This form not shown here.



# PROBLEMS

## CHAPTER 1

1. Define motion and time study according to (a) Taylor, (b) Gilbreth, and (c) Farmer.<sup>1</sup>
2. Explain fully the meaning of the phrase "most economical way of doing work."
3. What does the field of industrial engineering include? Show how motion and time study fits into this picture.

## CHAPTER 2

4. Give a sketch of the life of Frederick W. Taylor.
5. Summarize Taylor's investigations of: (a) handling pig iron; (b) cutting metals; (c) shoveling.
6. Give a sketch of the life of Frank B. Gilbreth.
7. Summarize Gilbreth's investigations of: (a) bricklaying; (b) work at the New England Butt Company; <sup>2</sup> (c) work for the handicapped.<sup>3</sup>
8. Give the chief criticisms of motion and time study and evaluate each.

## CHAPTER 3

9. What factors affect the extent to which motion and time study may be profitably used?
10. Indicate the extent of a motion and time study investigation for a department in a plant with which you are familiar.
11. Explain the "law of diminishing returns," in relation to the desirable elaborateness of a motion and time study program in a plant.

## CHAPTERS 4, 5, AND 6

12. Suggest changes that could be made which would reduce the time and effort required to get ready to water the garden. (See Figs. 7 and 8 on pages 32 and 33.) Make a process chart and a flow diagram of your proposed method.

<sup>1</sup> Eric Farmer, "Time and Motion Study," Industrial Fatigue Research Board, Report 14, H. M. Stationery Office, London, 1921. Also see C. S. Myers, "Industrial Psychology in Great Britain," Jonathan Cape, London, 1926; M. S. Viteles, "Industrial Psychology," W. W. Norton & Co., New York, 1932.

<sup>2</sup> John G. Aldrich, "The Present State of the Art of Industrial Management," Discussion, *Transactions of the A.S.M.E.*, Vol. 34, pp. 1182-87, 1912.

<sup>3</sup> F. B. and L. M. Gilbreth, "Motion Study for the Handicapped," George Routledge & Sons, London, 1920.



13. Construct a process chart and flow diagram for the following:

- (a) Writing a letter and mailing it.
- (b) Making a cheese sandwich.
- (c) Making a small gear from a gray iron casting.
- (d) Dressing, having breakfast, and leaving the house in the morning.
- (e) Washing a bundle of clothes in a commercial or home laundry.

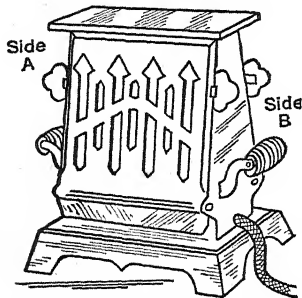


FIG. 310. Electric toaster.

14. Work out improvements in Problem 13 *a*, *b*, *c*, *d*, and *e* and construct a process chart and flow diagram of the new way.

15. The electric toaster shown in Fig. 310 is hand-operated, each side being operated independently of the other. A spring holds each side of the toaster shut, and each side must be held open in order to insert bread. In toasting three slices of bread in the above toaster, what method would you recommend to obtain the best equipment utilization—that is, the very shortest overall time? Assume that the toaster is hot and ready to toast bread.

The following are the elemental times necessary to perform the operations. Assume that both hands can perform their tasks with the same degree of efficiency.

Place slice of bread in either side of toaster	3 seconds
Toast either side of bread	30 seconds
Turn slice of bread on either side of toaster	1 second
Remove toast from either side of toaster	3 seconds

Make a man and machine chart of this operation.

16. Make a man and machine chart of washing a bundle of clothes in a home laundry or a commercial laundry.

## CHAPTER 7

17. Make a left- and right-hand operation chart of the following:

- (a) Filling a fountain pen.
- (b) Driving a nail in the end of a board.
- (c) Drilling a hole in the end of a square bar of steel.
- (d) Assembling mounting spring for refrigerator. (See Fig. 311 on page 526.)

18. Make a list of the motions of the left hand and of the right hand used in opening a bottle with the conventional type of bottle opener. The left hand reaches to back of table, gets bottle, carries it to front edge of table in convenient position for opening. The right hand already has the opener, moves it up to cap of bottle, and removes the cap, opening the bottle.

19. Work out a better method for assembling the rope clips. (See page 78.) Assume that there is sufficient production to keep two operators employed on this job forty hours per week during the next year. Make a left- and right-hand operation chart of your proposed method.



## CHAPTERS 8 AND 9

20. Why has micromotion study been used at such an accelerated rate in recent years?

21. Illustrate each of the 17 therbligs by means of an operation with which you are familiar.

## CHAPTER 10

22. Examine three different makes of motion-picture cameras and projectors and evaluate the important features of each for use in motion study and micromotion study work.

23. Explain the relationship between "speed" and "f. setting" of a camera.

24. Give the characteristics of ordinary panchromatic and supersensitive panchromatic motion-picture film when used in (a) daylight and in (b) artificial light (photoflood lamps).

25. Describe the use of an exposure meter.

## CHAPTER 11

26. Make a motion picture of:

- (a) Drilling  $\frac{1}{4}$ -inch hole in the end of a small steel shaft.
- (b) Picking up a fountain pen and writing.
- (c) Inserting a letter in an envelope and sealing it.
- (d) Stapling together two 3-inch by 5-inch cards.

## CHAPTER 12

27. Make an analysis sheet of the following operations. List the therbligs for both hands, omitting the time values.

- (a) Assembling the parts of a fountain pen cap.
- (b) Filling a fountain pen.
- (c) Assembling an automatic pencil.

28. Analyze the film of the operations in Problem 26 and record data on an analysis sheet similar to that shown in Fig. 79 on page 134.

29. Make a simo chart of the operations listed in Problem 26. Use a form similar to that shown in Fig. 80 on page 135.

## CHAPTER 13

30. Investigate several different methods of inserting folded letters and cards into envelopes. Is any one method superior to the rest? In what way?

31. Ten brass bolts  $\frac{3}{16}$  inch in diameter project 1 inch above a plastic molded plate in which the head has been imbedded.\* The bolts are 1 inch apart. Is it better to grasp several nuts at one time and hold them in the palm of the hand while assembling them onto the bolts, or is it better to grasp each nut separately? Explain.



## CHAPTER 14

32. What are the main criticisms of the common definition of fatigue?<sup>4</sup>
33. Study the reports of (a) The Industrial Health Research Board<sup>5</sup> and (b) the National Institute of Industrial Psychology<sup>6</sup> in Great Britain, and present a summary of the nature of the work of these two organizations.
34. Give a résumé of the results of the "Hawthorne Study" of the Western Electric Company.<sup>7</sup>

## CHAPTERS 15, 16, AND 17

Determine the most economical method of performing the operations described below. Prepare an instruction sheet (omitting the time for each element) of the proposed method showing the motions of the two hands. Include a layout of the work place.

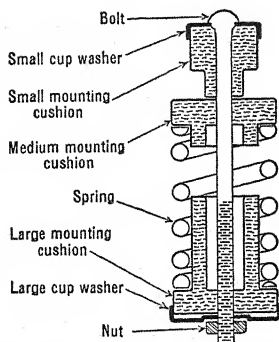


FIG. 311. Mounting spring for refrigerator.

35. The Sampson Paper Company folds 3,000,000 sheets of paper per year. The output consists of fourteen sizes of folded sheets, ranging from 3 inches by 5 inches to 10 inches by 12 inches. The paper is cut and sent to the folding department in bundles of approximately 500 sheets. The operator folds the sheets across the narrow width making a 3-inch by 10-inch flat sheet into a 3-inch by 5-inch folded sheet. After being folded, the sheets are "jogged" into a neat pile and a string is tied around the bundle of 100 sheets. The bundles are placed on the back of the work table.

36. An electrical appliance manufacturer has received an order for 50,000 connection plugs for attaching the cord to an electric iron. The plugs are to be shipped in equal installments of 2000 per day. Determine the most economical method of making the final assembly of this unit.

37. The Miller Refrigerator Company has received an order for 100,000 mounting springs similar to the one shown in Fig. 311. Determine the most economical method of assembling the parts.

38. A cabinet manufacturer uses several round-headed wood screw and washer assemblies (see Fig. 312) in the final assembly of one of his products. Orders on hand show that 100,000 of these assemblies will be needed each month for the next six months. On this basis (a total of 600,000 screw and washer assemblies) determine the most economical method for making the assemblies.

39. Make an eye-hand simo chart of an operation filmed in Problem 26.

<sup>4</sup> E. Mayo, "The Human Problems of an Industrial Civilization," Macmillan Co., New York, 1933.

<sup>5</sup> Reports published by H. M. Stationery Office, London.

<sup>6</sup> Official monthly publication *The Human Factor*, Aldwych House, London, W.C. 2.

<sup>7</sup> E. Mayo, *op. cit.*

T. N. Whitehead, "The Industrial Worker," Harvard University Press, 1938.

F. J. Roethlisberger and W. J. Dickson, "Management and the Worker," Harvard University Press, 1940.



## CHAPTER 18

40. Prepare a written standard practice for Problems 35 to 38 inclusive.

41. The London plant of an American manufacturing company is about to begin manufacturing metal boxes similar to the one shown in Fig. 55. The manager of the London plant has asked for a description of the method used by the parent plant. (a) Outline the essential information that should be included in a motion picture of a simple "blank and draw" operation required for making such a can. (b) Prepare the supplementary written data that should accompany the film.

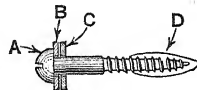


FIG. 312. Wood screw and washer assembly. A. Wood screw  $\frac{3}{16} \times 2\frac{1}{4}$  inches; B. Steel washer  $\frac{1}{2}$  inch outside diameter,  $\frac{7}{32}$  inch diameter of hole,  $\frac{1}{16}$  inch thick; C. Fiber washer; D. The point of the screw is coated with beeswax for a distance of 1 inch.

## CHAPTER 19

42. Give the arguments that are often presented in favor of time wage rather than an incentive wage for paying factory workers.

43. Interview 5 of your acquaintances who are now working in a factory or office. Analyze their comments on the subject of motion and time study.

44. You are the foreman of the assembly department of a plant manufacturing electrical supplies. A program of motion and time study has been in successful operation in your department for two years. John Willis, one of your best employees, asks you if the results of this work will not mean fewer jobs and less work for the employees in the plant. How will you answer?

## CHAPTERS 20, 21, AND 22

Make a stop-watch study of the following operations. Use the "average" method of selecting the time and include proper allowances. Make an instruction sheet for the operation.

45. Assembling parts of some small article such as a plug for attaching an electric iron.

46. Drilling a hole in a small piece held in a jig.

47. Turning a piece in a lathe.

48. Milling a piece strapped to the table.

49. Make a pinboard and pins according to the drawing shown in Fig. 313 and try the experiment described below.

(a) Determine the time required to fill the thirty holes in the board with thirty pins under each of the three conditions indicated in Fig. 314. Time five consecutive cycles and take the average.

(b) Determine the number of pinboards that could be filled in an 8-hour day under each of the three conditions. Assume that an operator could maintain the pace used in the experiment and that no fatigue nor delay allowances were made.

(c) Calculate in percentage how much more time was required to fill the pinboard under condition B than A; under condition C than A.



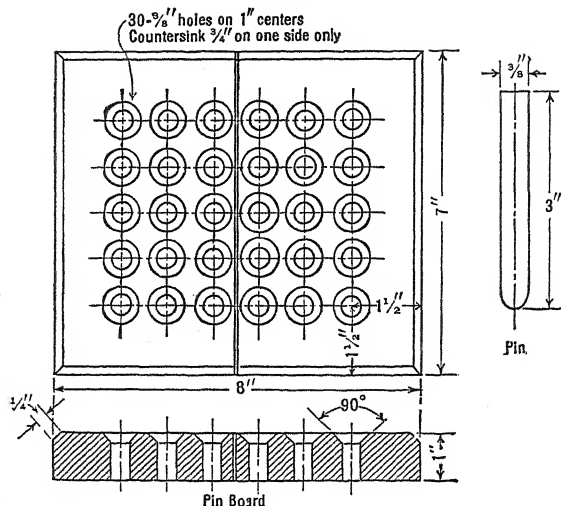


FIG. 313. Details for making pinboard and pins.

(d) Compute the total distance in feet through which the two hands would move in filling 1000 pinboards under each of the three conditions.

(e) Calculate in percentage how much farther the hands would move under condition B than A; under condition C than A.

50. Draw a frequency distribution curve of stature of registrants examined by Selective Service Boards. Use "Number of Men" in each height range as ordinant and "Height in Inches" (in groups of one inch) as abscissa.

Height in Inches	Number of Men	Height in Inches	Number of Men
59	1	69	141
60	3	70	118
61	5	71	90
62	11	72	58
63	22	73	30
64	41	74	15
65	69	75	6
66	103	76	3
67	133	77	1
68	150		

51. Determine the actual walking speed for men and women. Measure off 50 feet on a smooth, level sidewalk. Then from a point where you can see clearly this 50-foot section of sidewalk, with a decimal minute stop-watch determine the time required by individuals to walk this 50-foot distance. Obtain data on people walking singly rather than walking in groups. Also make the following classifications of your data: first, men and women; second, three age groups—15 to 18, 18 to 50, 50 to 70; and then under each of these age groups further subdivide the



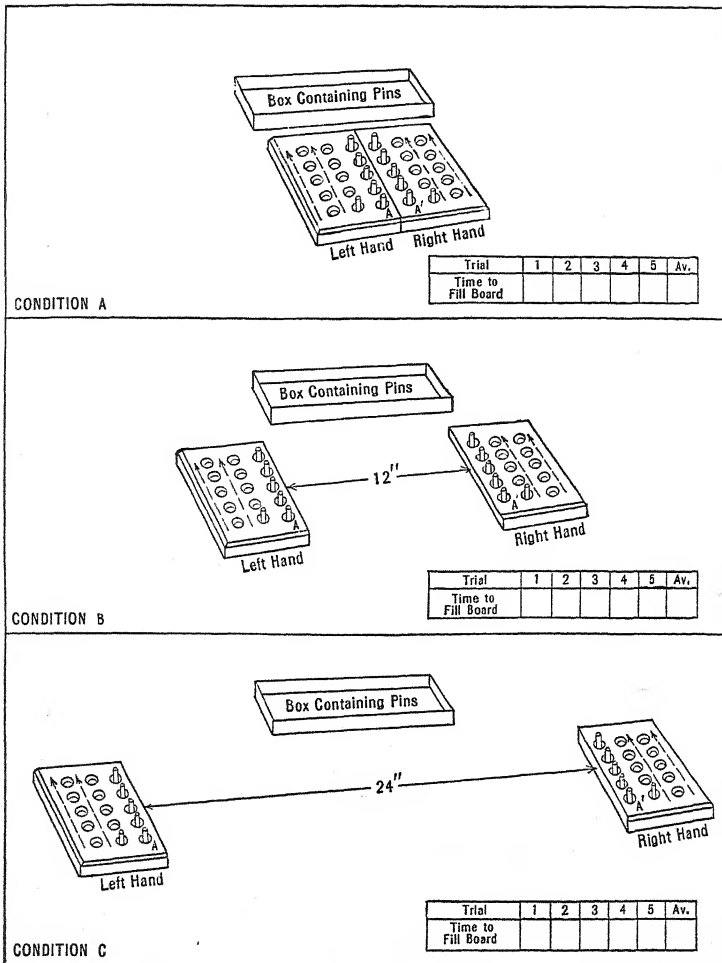


FIG. 314. Arrangement of work place for pinboard study.

people as to height—short, medium, and tall. The data might be recorded on the form shown below:

[illegible]



52. Make an eight-hour time study of a janitor, setup man, material handler, or other person on "indirect labor."
53. Make a random-check delay study of a factory or office activity.

## CHAPTER 23

54. Determine the standard time for drilling the part shown on sketch at the bottom of the observation sheet on page 345 if the piece is 1.750 inches in diameter and the actual drilling time is 0.94 minute. Use time-setting tables for the sensitive drill.
55. Determine the time required to mill the hexagon, using a gang mill, on part G12W-377A (Fig. 261 on page 398) if the dimension  $A$  (length of the hexagon) is 1.125 inches and all other dimensions are as shown.

## CHAPTER 24

56. Calculate the standard time for cutting teeth on feed change gear part 1060-AF (see Fig. 264 on page 410). Length of face 1.250 inches, diametrical pitch 10, number of teeth 60, spline bore, S.A.E. 2315, hob S10R, plain spur gear. Size of order 50 gears.
57. Determine the standard time required for the operation "solder the side seam" of rectangular can with the following dimensions: length 8.125 inches, width 1 inch, depth 8.5 inches.

## CHAPTER 25

58. Determine the standard time required to perform operation 4. "Work out shape through die block" for the blank for the part shown in Fig. 267 on page 421. The blank is 2.00 inches square with round corners of  $\frac{1}{4}$ -inch radius. Quality required is Class B.

## CHAPTERS 26 AND 27

59. Determine the standard time to load and unload the fixture shown in Fig. 315.

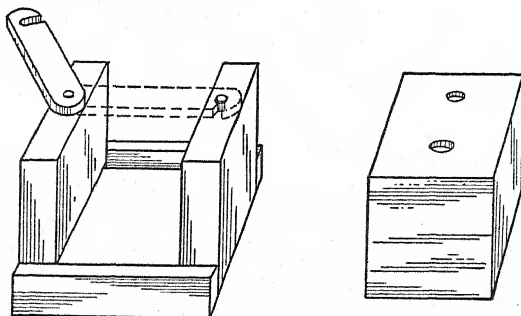


FIG. 315. Fixture for drill-press work.



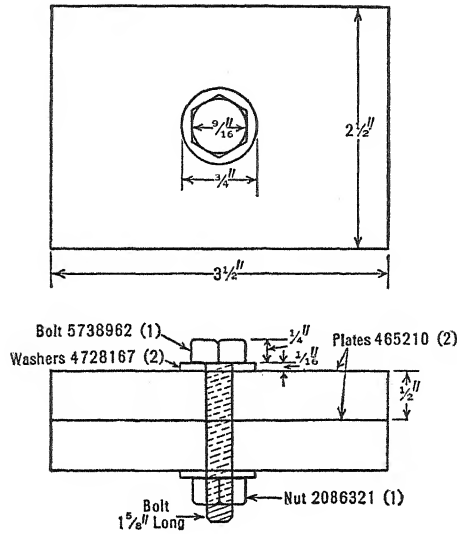


FIG. 316. Plate assembly.

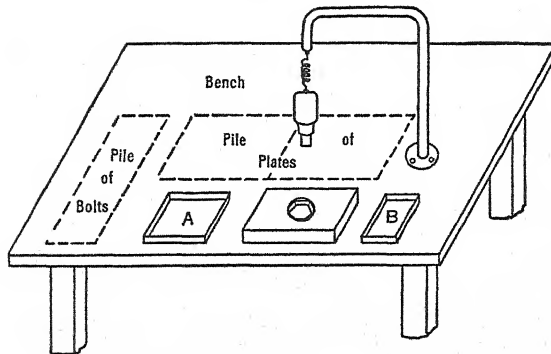


FIG. 317. Arrangement of the work place for the plate assembly.



60. (a) Determine the standard time required to "assemble two plates, two washers, bolt, and nut," as shown in Fig. 316. The arrangement of the work place is shown in Fig. 317, and the sequence of motions for the right hand and the left hand is given below.

## SEQUENCE OF MOTIONS

Operation—Assemble 2 plates, 2 washers, bolt, and nut	
Left Hand	Right Hand
Get nut from tray A T. E. + G. Place nut in fixture (nest) T. L. + P. + R. L.	Get washer from tray B T. E. + G. U. D.  Place washer in fixture (nest) over nut T. L. + P. + R. L. Get plate from pile T. E. + G. U. D.
Get plate from pile T. E. + G. Place plate in fixture T. L. + P. + R. L.	Place plate in fixture T. L. + P. + R. L. Get washer from Tray B T. E. + G. Place washer on plate over hole T. L. + P. + R. L. Get power driver T. E. + G. Place driver on bolt head T. L. + P. + R. L.
Get bolt from pile T. E. + G. U. D.  Place bolt in hole T. L. + P. + R. L. U. D.	Use time—drive bolt Dispose of driver T. L. + P. + R. L.
Get completed assembly T. E. + G. Place aside on bench T. L. + P. + R. L.	

(b) If the plates were placed in one pile rather than two, what difference would it make in the assembly time?

(c) How much faster would it be if a dual fixture were used?

(d) Would it be advantageous to mount the driver under the bench and drive the nut from below? How might such a setup be arranged?

(e) In the present layout the washer is placed over the hole on the plate. Would it be quicker and easier to assemble the washer to the bolt first? Design a fixture which would make such an arrangement possible. Determine the standard time.



61. Determine the standard time required for the method shown in Figs. 256 and 257.

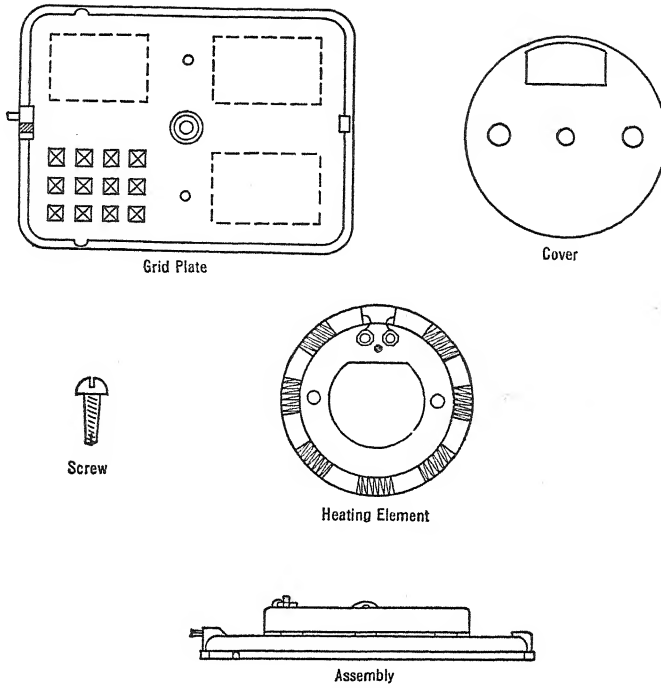


FIG. 318. Parts for heating element assembly.

62. (a) Determine the standard time required to "assemble heating element to grid," as shown in Fig. 318. The arrangement of the work place is shown in

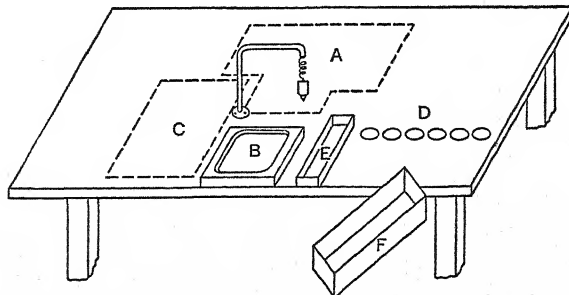


FIG. 319. Arrangement of the work place for the assembly of heating elements.

Fig. 319, and the sequence of motions for the right hand and the left hand is given on the next page.



## SEQUENCE OF MOTIONS

Operation—Assemble heating element to grid	
Left Hand	Right Hand
Get aluminum grid from pile A on bench T. E. + G. Place in fixture B	Get aluminum grid from pile A on bench T. E. + G. Get heating element from pile D on bench (from next bench) T. E. + G. Place heating element in position on aluminum grid
Get cover from pile C on bench  T. E. + G. Place cover over heating element T. L. + P. + R. L. Get power driver T. E. + G. Place driver on screw T. L. + P. + R. L.	T. L. + P. + R. L. Get screw from tray E T. E. + G. Place screw in hole T. L. + P. + R. L. (Guide screw)
Place driver aside T. L. + P. + R. L. U. D.	Use time—drive screw Get assembled part T. E. + G. Place assembled part (in pairs) aside in tote box F T. L. + P. + R. L.

(b) If tray E containing the screws were placed on the left-hand side of the work place alongside covers at C, what difference would it make in the total assembly time? Make up chart showing motion sequence with this rearrangement of parts.

## CHAPTER 28

63. Work out a motion and time study training program for foremen and supervisors for a specific plant in your locality.

64. Make rating study of walking.

*Object*

To obtain practice in rating operator performance.

*Equipment and materials needed*

1. Decimal minute stop-watch, steel tape, chalk, string.
2. Rating Form: B204.

*Place*

Select a room with smooth level floor or use a smooth level sidewalk.



*Procedure for conducting rating study*

1. Measure off 50 feet of unobstructed floor space, marking a starting and stopping line on the floor and allowing 10 or 15 feet of additional space at either end for the operator to start and stop. Tie a string to the back of one chair and throw it loosely across the back of another chair so that the string is stretched directly above the starting line on the floor. Also place a string across two chairs at the other end of the 50 feet. These strings are to help the operator to start his watch and read his watch at the proper instant.
2. Have someone (this person will be called the operator) practice walking the 50 feet at exactly 3 miles per hour. This practice should take place before the group assembles. The operator should take 0.189 minute to walk the 50 feet. After a little practice it will not be difficult for the operator to walk the 50 feet in this time or at a speed of 3 miles per hour. Table LI shows the time needed for the operator to walk 50 feet at other speeds.

TABLE LI

## CONVERSION OF WATCH READINGS TO WALKING SPEEDS AND PERFORMANCE RATINGS

Time in minutes to walk 50 ft.	.120	.125	.130	.135	.140	.145	.150	.155	.160	.165	.170	.175	.180	.185
Actual speed in miles per hour	4.72	4.54	4.35	4.20	4.05	3.91	3.78	3.66	3.54	3.44	3.34	3.24	3.15	3.06
Rating in % (3 m.p.h. = 100%)	158	151	145	140	135	130	126	122	118	115	111	108	105	102

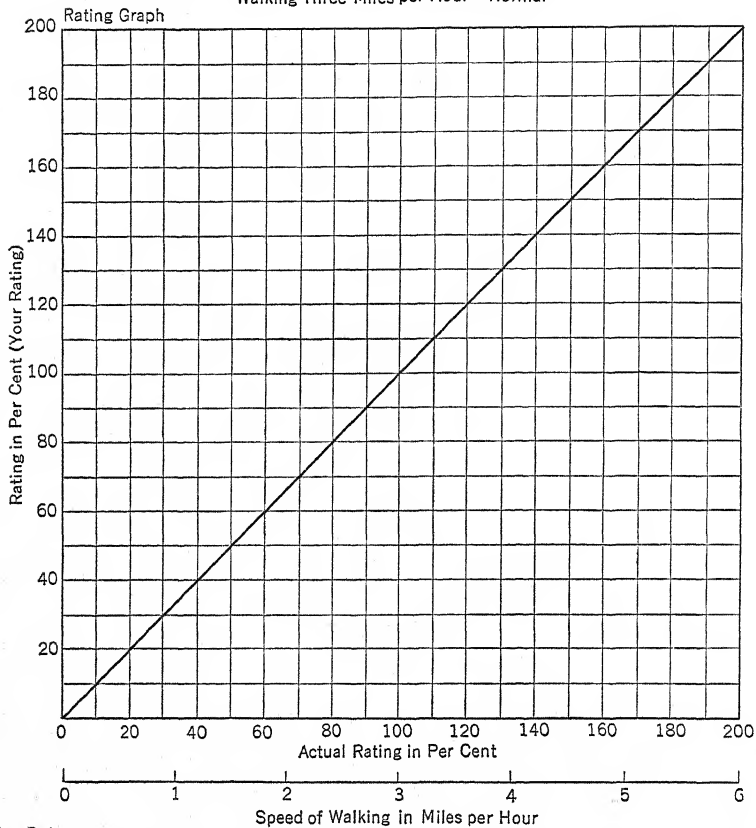
  

Time in minutes to walk 50 ft.	.189	.190	.195	.200	.205	.210	.215	.220	.225	.230	.235	.240	.245	.250
Actual speed in miles per hour	3.00	2.98	2.91	2.84	2.77	2.70	2.64	2.58	2.52	2.47	2.41	2.36	2.31	2.27
Rating in % (3 m.p.h. = 100%)	100	99	97	95	92	90	88	86	84	82	80	79	77	76

3. Provide each person with a data sheet similar to Form B204. (See Fig. 320.) Have him fill in his name and the date at the bottom of this form. No stop watch or clock is to be used by members of the group in this study.
4. The operator then walks at 3 miles per hour, and the group is told that this speed represents a rating of 100 per cent. Two or three trials are made at this speed. The operator times himself, and if he takes more or less than 0.189 minute to walk the 50 feet he informs the group of that fact and immediately determines the actual speed in per cent, which he gives to the group. The group, of course, makes no record of these preliminary trials.
5. The operator then walks the 50 feet ten different times, called trials, varying his speed at random. At the end of each trial he records on his data



PERFORMANCE RATING DATA SHEET AND RATING GRAPH FOR WALKING  
Walking Three Miles per Hour = Normal



## Rating Data

Trial No.	1	2	3	4	5	6	7	8	9	10	Systematic Error	Absolute Error
Your Rating In Per Cent												
Actual Time in Min. to Walk 50 Ft.												
Actual Rating												
Difference												

Rating Made by \_\_\_\_\_ Date \_\_\_\_\_

B204

FIG. 320. Performance rating data sheet for walking.



sheet the actual time it took him to walk the 50 feet and the corresponding rating in per cent. This information ordinarily is not given to the group until all ten trials are finished, although the correct ratings may be announced immediately after each trial. The walking speeds should fall between approximately 2.5 miles per hour (85 per cent of normal) and 4.5 miles per hour (150 per cent of normal), inasmuch as working speeds in practice are usually within these limits. It is considered more difficult to rate accurately when extremes are encountered.

6. Each person watches the operator walk the 50 feet and rates him, using 100 per cent = 3 miles per hour as normal. Each trial is recorded in per cent on the first horizontal line at the bottom of Form B204.
7. Then read the correct ratings in per cent, and ask each person to copy these ratings on the third horizontal line at the bottom of Form B204.
8. Ask each person to plot his ratings on the Rating Graph. Each person should then draw a straight line through the average position of these points.
9. Compute the systematic error, mean deviation, and absolute error for each person and for the group.<sup>8</sup>
10. Repeat this walking experiment each week until there is no further improvement. Use the same person as the subject or "operator" throughout the experiment.

65. Make rating study of dealing cards.

#### *Object*

To obtain practice in rating operator performance.

#### *Equipment and materials needed*

1. Decimal minute stop-watch, deck of cards, card table.
2. Rating Form: B205.

#### *Place*

Select a room large enough to accommodate the group of people who will participate in the study.

#### *Procedure for conducting rating study*

1. Have someone (this person will be called the operator) practice dealing the deck of cards in four equal piles in one-half minute. Another person, called the timer, will by means of a stop-watch time the operator and record the total time for dealing the deck. If the operator takes more or less than one-half minute to deal the deck, the timer informs the group of this fact, and he immediately determines the actual speed in per cent, which he gives to the group. The group, of course, makes no record of the preliminary trials. The operator is seated and deals a standard deck of 52 cards in the following way: The deck is held in the left hand and the top card is positioned with the thumb and index finger of the left hand. The right hand grasps the positioned card, carries, and tosses it onto the table. The four piles of cards are arranged on the four corners of a one-foot square. The only requirement is that the cards shall all be face down and that each of the four piles shall

<sup>8</sup> "Work Measurement Manual," 3rd ed., pp. 81-87, 1947.



be separate from the others. Care should be used to make certain that the method does not deviate from this as the speeds are varied. After a little practice, the operator can deal the cards in exactly one-half minute or at 100 per cent rating. Table LII shows the time required to deal the cards at other speeds.

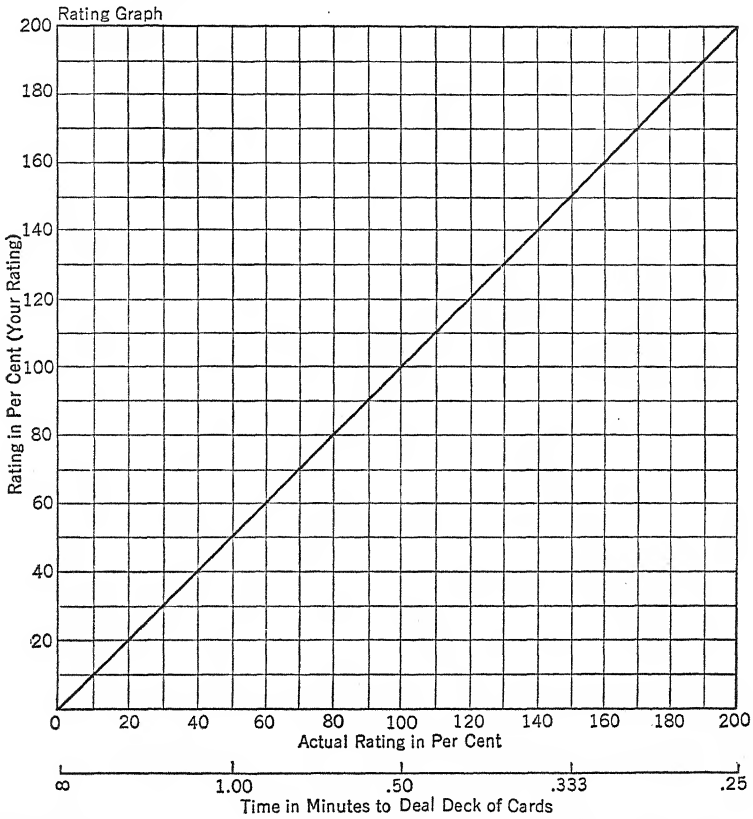
TABLE LII

CONVERSION OF WATCH READINGS TO PERFORMANCE RATINGS FOR DEALING CARDS

Time in minutes to deal deck of cards	.313	.314	.316	.318	.321	.323	.325	.327	.329	.331	.333	.336	.338
Rating in per cent .500 min. = 100%	160	159	158	157	156	155	154	153	152	151	150	149	148
Time in minutes to deal deck of cards	.340	.342	.345	.347	.350	.352	.355	.357	.360	.362	.365	.368	.370
Rating in per cent .500 min. = 100%	147	146	145	144	143	142	141	140	139	138	137	136	135
Time in minutes to deal deck of cards	.373	.376	.379	.382	.385	.388	.390	.394	.397	.400	.403	.407	.410
Rating in per cent .500 min. = 100%	134	133	132	131	130	129	128	127	126	125	124	123	122
Time in minutes to deal deck of cards	.413	.417	.420	.424	.427	.431	.435	.439	.442	.446	.450	.455	.459
Rating in per cent .500 min. = 100%	121	120	119	118	117	116	115	114	113	112	111	110	109
Time in minutes to deal deck of cards	.463	.467	.472	.476	.481	.485	.490	.495	.500	.505	.510	.515	.521
Rating in per cent .500 min. = 100%	108	107	106	105	104	103	102	101	100	99	98	97	96
Time in minutes to deal deck of cards	.526	.532	.538	.543	.549	.556	.562	.568	.575	.581	.588	.595	.602
Rating in per cent .500 min. = 100%	95	94	93	92	91	90	89	88	87	86	85	84	83
Time in minutes to deal deck of cards	.610	.617	.625	.633	.641	.649	.658	.667	.676	.685	.694	.704	.714
Rating in per cent .500 min. = 100%	82	81	80	79	78	77	76	75	74	73	72	71	70



PERFORMANCE RATING DATA SHEET AND RATING GRAPH FOR DEALING CARDS  
Dealing Deck into Four Piles in 0.50 Minute = Normal



## Rating Data

Trial No.	1	2	3	4	5	6	7	8	9	10	Systematic Error	Absolute Error
Your Rating in Per Cent												
Actual Time in Min. to Deal Cards												
Actual Rating												
Difference												

Rating Made by \_\_\_\_\_ Date \_\_\_\_\_

B205

FIG. 321. Performance rating data sheet for dealing cards.



2. Provide each person with a data sheet similar to Form B205. Have him fill in his name and the date at the bottom of this form. No stop-watch or clock is to be used by members of the group in this study.
3. The operator then deals the deck of cards in one-half minute, and the group is told that this speed represents a rating of 100 per cent. Two or three trials are made at this speed.
4. The operator then deals the deck ten different times, called trials, varying the speed at random. At the end of each trial the timer records the time and shows it to the operator but does not give this information to the group until after all ten ratings have been made. The speeds should fall between approximately 85 per cent of normal (dealing deck in 0.588 minute) and 150 per cent of normal (dealing deck in 0.33 minute), inasmuch as working speeds in practice are usually within these limits. It is considered more difficult to rate accurately when extremes are encountered.
5. Each member of the group watches the operator deal the deck of cards and rates him, using 100 per cent =  $\frac{1}{2}$  minute as normal. Each trial is recorded in per cent on the first horizontal line at the bottom of Form B205. (See Fig. 321.)
6. Then read the correct ratings in per cent and ask each person to copy these ratings on the third horizontal line at the bottom of Form B205.
7. Ask each person to plot his ratings on the Rating Graph. Each person should then draw a straight line through the average position of these points.
8. Compute the systematic error, mean deviation, and absolute error for each person and for the group.
9. Repeat this card dealing experiment each week until there is no further improvement. Use the same person as the subject or "operator" throughout the experiment and make certain that the same method of dealing the cards is used.

#### CHAPTER 29

66. Discuss the advantages and the disadvantages of training the operator at the machine vs. training in a separate training school.
67. Indicate the training that would be given to a new employee beginning work on operations described in Problems 35 and 37.
68. What would be the ultimate effect on the personnel of an organization of a training program in principles of motion economy for every new employee?



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## ILLUSTRATIONS FROM OTHER BOOKS BY THE AUTHOR

The following illustrations were taken from "Work Methods Manual," by Ralph M. Barnes, published by John Wiley & Sons, Inc., New York:

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 1. The two hands should begin as well as complete their motions at the same time, 193

Principles of motion economy (*Cont.*)  
 2. The two hands should not be idle at the same time except during rest periods, 193  
 3. Motions of the arms should be made in opposite and symmetrical directions and should be made simultaneously, 193  
 4. Hand motions should be confined to the lowest classification with which it is possible to perform the work satisfactorily, 216  
 5. Momentum should be employed to assist the worker wherever possible, and it should be reduced to a minimum if it must be overcome by muscular effort, 218  
 6. Smooth continuous motions of the hands are preferable to zig-zag motions or straight-line motions involving sudden and sharp changes in direction, 219  
 7. Ballistic movements are faster, easier, and more accurate than restricted (fixation) or "controlled" movements, 224  
 8. Rhythm is essential to the smooth and automatic performance of an operation, and the work should be arranged to permit easy and natural rhythm wherever possible, 226  
 9. There should be a definite and fixed place for all tools and materials, 229  
 10. Tools, materials, and controls should be located close in and directly in front of the operator, 231  
 11. Gravity feed bins and containers should be used to deliver the material close to the point of use, 245  
 12. "Drop deliveries" should be used wherever possible, 251  
 13. Materials and tools should be located to permit the best sequence of motions, 253



Principles of motion economy (*Cont.*)

14. Provisions should be made for adequate conditions for seeing. Good illumination is the first requirement for satisfactory visual perception, 261
  15. The height of the work place and the chair should preferably be arranged so that alternate sitting and standing at work are easily possible, 271
  16. A chair of the type and height to permit good posture should be provided for every worker, 276
  17. The hands should be relieved of all work that can be done more advantageously by a jig, fixture or a foot-operated device, 280
  18. Two or more tools should be combined wherever possible, 293
  19. Tools and materials should be pre-positioned wherever possible, 295
  20. Where each finger performs some specific movement, such as in typewriting, the load should be distributed in accordance with the inherent capacities of the fingers, 298
  21. Handles such as those used on cranks and large screwdrivers should be designed to permit as much of the surface of the hand to come in contact with the handle as possible, 301
  22. Levers, crossbars, and hand wheels should be located in such positions that the operator can manipulate them with the least change in body position and with the greatest mechanical advantage, 305
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